A

COURSE

OF

Experimental Philoſophy.

BY

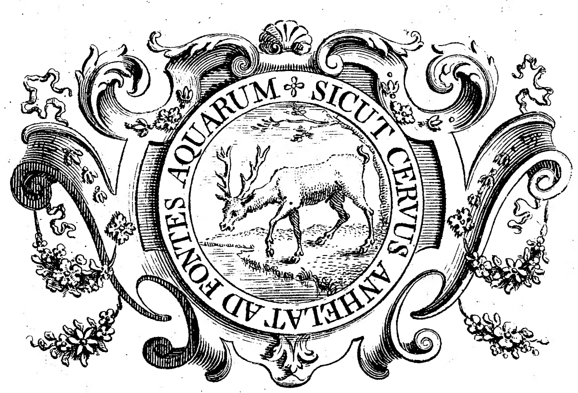
J. T. DESAGULIERS, LL. D. F. R. S.

Chaplain to HIS ROYAL HIGHNESS
FREDERICK, PRINCE of WALES, *&c.*

Formerly of *Hart-Hall* (now *Hertford-College*) in *Oxford*.

VOL. II.

Adorn'd with Forty-ſix COPPER-PLATES.



LONDON:
Printed for W. INNYS, at the Weſt End of *St Paul's*; M. SENEX,
in *Fleet-ſtreet*; and T. LONGMAN, in *Pater-noſter-Row*.
M. DCC. XLIV.

Nov. 17. 1743.

At a Meeting of the ROYAL SOCIETY,

Imprimatur,

M. FOLKES, Pr. R. S.

HUMBLY INSCRIB'D TO

FREDERICK, PRINCE of WALES,

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By HIS ROYAL HIGHNESS'*s*

most Oblig'd

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and most Devoted

SERVANT,

CHAPLAIN,

and EXPERIMENTAL PHILOSOPHER,

J. T. DESAGULIERS, LL. D. F. R. S.

The PREFACE.

THIS *second Volume has more need of an Apology than a Preface, upon many Accounts; first upon Account of the Time, that it has been delay'd, when it should immediately have follow'd the First, which Delay was occasion'd by the Promise I made in my First Book to decide the Question about the* Force of Bodies in Motion, *which has now been a Subject of Dispute about* 59 *Years; the Gentlemen of* Germany, Italy *and* Holland *measuring that* Force *by the* Product of the Mass into the Square of the Velocity of the Body; *and those of* France *and* England *measuring that Force by the* Product of the Mass into the simple Velocity.

I could not quit my Conviction in favour of the old Opinion, as it was supported by Demonstration; but yet could not find any want of Accuracy in several of the Experiments I examin'd, which were made to prove the new Opinion: neither could I find any Fallacy in the reasoning from those Experiments; tho' I thought it must be want of Penetration in me that I could not perceive it, supposing that both Opinions could not be true. At last, as I was often blam'd for not publishing my second Volume, I resolv'd to satisfy my Subscribers, and to mention the principal Arguments and Experiments alledg'd for both Opinions; but my Friend Mr. Professor P. V. Muschenbroek *sending me word, that he begg'd I would postpone publishing my second Volume till I had read Dr.* 'sGravesande's *last Edition of his Philoso-*

phy;

phy; I complied with his Desire, and examining every thing again with Care, found that the Philosophers on both Sides were right in the main; but only so far wrong, as they attributed to their Adversaries Opinions, which they had not: and that the whole was only a Dispute about Words; the contending Parties meaning different Things by the Word Force. *If I have succeeded in reconciling this Matter, the Professor* Muschenbroek *deserves the Praise of it, by whose Love of Impartiality I was prevail'd upon to examine all the Arguments anew.*

I hope this will satisfy such as have thought my Delay too long; but some of my Subscribers may be displeas'd that I have not exactly complied with my Proposals given out before the Publication of the first Volume; till I let them know that it is owing to a great Majority of the Subscribers that I have alter'd my first Design, and made my second Volume what it is now. As my curious Friends know, that I have made the Consideration of Water-Engines my Study for many Years; they desir'd that I would fully treat upon that Subject by Rules deduc'd from my Hydrostatical and Pneumatical Lectures, and give a Description of a sufficient number of Engines to make the Practice of so useful an Art easy. Because tho' we have many Draughts of Machines, we have but superficial Descriptions of them. And where we have some Calculations, they are too abstracted; and we have no certain Rules to direct us that we may not be impos'd upon by ourselves, nor suffer mechanical Undertakers to impose upon us. I have complied with this Desire, which has swell'd out the Volume of my Book so as to leave no room for the Opticks, which I had formerly promis'd to give; for the Book now contains above 100 *Pages, or* 12 *Sheets more than my first Volume, and there are* 22 *large additional*

additional Copper-Plates, (the Plates of this Volume being in all 46*) which has ſwell'd the Book to as large a Bulk as can well be bound in one Volume.*

As the Treatiſe of Opticks, I deſign'd to publiſh, was only intended to be eaſy and popular; I refer the Readers who are deſirous of ſeeing the Subject treated of in that manner, to the Book of Opticks publiſh'd by the Reverend and Learned Dr. Smith, *Maſter of* Trinity College *in* Cambridge, *where that Part which he calls* Popular *Opticks will give them full Satisfaction.*

All that I have new in Opticks, as alſo my explicit Deſcription of making ſeveral of Sir Iſaac Newton's *Experiments to make them eaſy in the Execution; (becauſe ſeveral People have fail'd in their Attempts, for want of ſome cautionary Directions) is to be met with in the Philoſophical Tranſactions, Numbers* 348, 360, 361, 374, 406. *And this I hope will plead my Excuſe. But ſtill I muſt apply farther to my Subſcribers, in deſiring them not to think it too much to pay* 18 *Shillings for this Volume in Sheets, or one Guinea bound; the Expence which has brought it to this Bulk and Number of Plates, being the double of what was firſt intended. Beſides, thoſe that think it too dear, need not take it. But I hope at laſt I have one Merit to plead; which is, that I have put it out of the power of any Perſon to be impos'd upon for the future, by thoſe that pretend to great Performances in Water-Works, by ſhewing the utmoſt that can be done that way, as the Reader may find in that Part of my Book that treats of Engines. And it is this: No Man muſt hope that with any Engine in the World, a Man ſhall raiſe more than* one Hogſhead of Water ten Feet high in a Minute, *with moderate Work, or ſuch as he may*

hold all Day: nor an Horſe above one Hogſhead 50 Feet high in the ſame time.

This is a very neceſſary Caution; for there are ſeveral Perſons who have Money, that are ready to ſupply boaſting Engineers with it, in hopes of great Returns; and eſpecially if the Project has the Sanction of an Act of Parliament to ſupport it——and then the Bubble becomes compleat, and ends in Ruin.

About two Years ago a Man propos'd an Engine, to raiſe by one Man's Work about ten times more Water than was poſſible to a certain Height in a certain Time; for which he wanted an Act of Parliament, and got a Report of the Committee, appointed to examine the Matter, That he had made out the Allegation of his Petition. *If this had paſs'd, a great many Perſons were ready to ſubſcribe conſiderable Sums to the Project; which Money of courſe would all have been loſt, and perhaps ſome Families ruin'd; but a Nobleman, who underſtands the Nature of Engines very well, knowing the Impoſſibility of what was propos'd, threw out the Bill.*

Our Legiſlators may make Laws to govern us, repeal ſome, and enact others, and we muſt obey them; but they cannot alter the Laws of Nature; nor add or take away one ιωτα *from the Gravity of Bodies.*

AN

THE

NAMES of ſuch Perſons,

As have encouraged this

WORK

BY THEIR

SUBSCRIPTIONS.

His Late Majeſty King GEORGE the Firſt,

HIS PRESENT MAJESTY,

HER LATE MAJESTY.

[*N. B.* The SUBSCRIBERS NAMES being moſtly copied from the firſt Volume, in the Author's Abſence from *London*; 'tis to be hoped no Gentlemen, whoſe Titles have been alter'd ſince their firſt Subſcription, will take it ill, that they are not alter'd here.]

N. B. Those that have this Mark (*) have only subscrib'd to the SECOND VOLUME.

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ERRATA.

P. 473. l. 32. *read*, Air will precipitate in Steam, as Quickſilver would in Water.

P. 558. l. 8. *dele* of the Braſs.

A

COURSE

OF

Experimental PHILOSOPHY.

LECTURE VI.

Concerning the Congreſs of Bodies.

1. THE Doctrine of the Congreſs of Bodies, (or of the Effects arising from the Stroke of Bodies that come againſt each other in the ſame, oppoſite, or oblique Directions, and under various Circumſtances) is ſo extenſive *; that there is hardly any Machine (eſpecially any compounded one) contriv'd for the Uſes of Life, to which it is not applicable: and ſeveral Philoſophical Truths are alſo deduc'd from it.

* Ann. 1.

THOSE who are not much accuſtom'd to apply Mathematical Theories to the erecting and working of Engines, but rather conduct their Practice by what they have ſeen good in ſome Machines, and ſhunning the Errors that they have obſerv'd in others, may find by reading ſome of the Notes to this Lecture with attention, that making Experiments on pendulous Balls of different kinds ſtriking againſt each other, is not matter of meer Curioſity; but that from the Effects of ſuch Shocks or Strokes carefully obſerv'd, Rules may be drawn whereby they may contrive ſuch Machines *à priori*, that they may always be ſure of what the Effect of the Performance will be: whereas, without theſe Rules, Mechanical Artiſts only go on by gueſs-work.

Lect. VI. 2. As all Bodies, in respect of their striking against each other, may be consider'd as having Elasticity or having none, or as the Elasticity they have is more or less perfect; it will not be improper, before we come to consider this Subject particularly, to say something concerning Elasticity.

3. That Property which some Bodies, whose Figure (or the Position of whose Parts) has been alter'd, have of restoring themselves, when the Force which alter'd their Figure has been remov'd, is call'd their *Elasticity*. This will be further illustrated by the following Experiments.

Experiment I. *Plate* I. *Fig.* I.

Plate I. Fig. I. 4. Let a Wire or a Cat-gut String, as A B, be stretch'd upon a Table, (a little above it so as not to touch it) by twisting one of the Fiddle-Pins A or B, to which it is fastned. Then taking hold of the middle of it, bring it to D, so as to stretch the String, and put it into the Position A D B; from which, as soon as you let it go, it will restore itself into the Position A B; and the Force whereby it does it, is call'd its Elasticity.

5. The Cause of this Property in Bodies is as much unknown as the Cause of Gravity. There have been indeed several Conjectures about it; but as in the *Newtonian* Philosophy Conjectures are never given for Solutions, I shall not quote them here: only I shall mention them in the Notes, not as true, but probable Causes *. * Ann. I.

6. When the String from the Position A D B is by its Elasticity return'd to the Position A B, it will not remain there, but by the first Law of Nature will go on till it comes to C, where it has lost all its Motion. Then by the Elasticity and first Law, it will go back again towards D, then again towards C; and so alternately for some time, vibrating like a Pendulum, so as to lose a little of its Motion every time, till it comes to rest at last, all the Vibrations, as C D, *c d*, $\kappa\delta$, being isochronal, as in a Pendulum. *N. B.* If there was no Resistance of Air, nor Friction, at the Centers A and B, and the Elasticity of the String was perfect, such a String wou'd vibrate perpetually.

Whether the middle of the String A B be brought quick or slowly to the Point D, it sets out with the whole accumulated Force with which it has been bent, whereby it accelerates its Motion till it comes to the Line A B, then goes with a retarded Motion towards C; as we have L. 5. N° 78. taken notice of in the first Volume, when we spoke of the *Bow* or *Spring*.

Experiment

EXPERIMENT 2. *Plate* 1. *Fig.* 2.

7. HAVING fixed the String parallel to the Table by two little Supports or Bridges A B *, of the same height, take a Ball of any hard Substance, as Ivory, Brass, or any Metal, whose Diameter is equal to twice the Distance of the String from the Table: then instead of pulling the String at *c*, roll the Ball M against it pretty strongly in the Direction M *c*, and the Ball will drive the Point *c* in the Direction *c* C, till having discharg'd all its Force on the String, it has lost all its Motion when the Point *c* is come to C. By this means the Elasticity of the String is so far rais'd, that in its Return it restores to the Ball M all the Motion that it had lost in bending the String, because Action and Reaction are equal.

* Plate 1. Fig. 2.

8. WHETHER the String be struck perpendicularly or obliquely, in the very Middle, or towards either End; the Reaction of the String is always in Lines perpendicular to it, as is the Case of the Surface of elastick Bodies that are struck. For if you press the Ball against the String, so as to bend it at the Points E or F, it will (upon the Removal of your Hand) by the Resilition of the String fly back in the Line E G or F H. And tho' when the Ball is roll'd against the String in the oblique Direction G *c*, it returns obliquely in the Direction *c* H, so as to make the Angle of Reflection M *c* H equal to the Angle of Incidence G *c* M; yet that Effect arises from the Reaction of the String in a Direction perpendicular to it, as may be easily known by calling to mind what has been said in the first Volume concerning oblique Strokes and compound Motion *; some Part of which we will repeat here.

* Sect 3. N° 85. & Ann. 5 & 7. L. 5. N° 3. & Ann. 1.

9. LET the Motion of the Ball in the Line G *c* be resolv'd into two Motions, or the Motions produced by the Action of two Forces in the Directions G E and G D, one of which (G E) is perpendicular, and the other (G D) parallel to the String A B. Now as the Force acting in the Direction G D does not bring the Ball towards the String, that Force is not at all lost by the Stroke; and as only the Force acting in the Direction G E pushes the Ball against the String at *c*, the same Effect is produc'd as if the Ball had mov'd all along D *c* in the same time that it mov'd along G *c*. But this last Force being wholly spent in bending the String at *c*, and raising its Elasticity, the Resilition of the String acts upon the Body with an equal Force in the Direction *c* D: but the Force G D, (which not having been destroy'd, still subsists) being now transferr'd to *c* F, the Ball is acted upon by two Forces, whose Quantities and Directions being represented by *c* F and *c* D, (the two contiguous

Lect. VI. Sides of the Parallelogram C D H F) and therefore must move in the Line *c* H Diagonal of the said Parallelogram and oblique to A B. *Which was to be shewn.*

10. We may consider all elastick Bodies as made up of such Strings as A B *, or rather of elastick *Strata* parallel to each other, whose Effect we will consider in what happens to an elastic Ball. *See Fig.* 3. where A B represents those *Strata*. If the Ball be struck at D by an hard or an elastick Body, all the *Strata* will be bent in towards C, as the prick'd Lines represent, whilst the Ball is flatten'd or dented in at D; but the *Strata* quickly restoring themselves, the Surface of the Ball reassumes its first Figure, and that more or less exactly according to the Degree of Perfection of the Elasticity of the Ball. That the *Strata* are bent in, or the Force of the Stroke reaches as far as the Center, is plain by the following Experiment.

* Plate 1. Fig. 3.

Experiment 3.

I took an Ivory Ball of an Inch and half Diameter, and having suspended it by a String about 40 Inches long to one of the Center Pins of an Instrument to hang pendulous Bodies on, (see Pl. 26. F. 12. Vol. 1.) to which was hanging from the same Height another Ivory Ball of four times the Weight, and having rais'd up the first Ball several times to the same Height, that it might strike the other Ball which was at rest with the same Force, I observ'd upon the Degrees of the graduated Arch before which it mov'd, to what Degree it return'd by its Recoil, which was always the same when it struck the other Ball full. Then having caused a cylindrick Hole to be turn'd out of this smallest Ivory Ball a little beyond its Center, I stopp'd the Hole by screwing in another Piece of Ivory, which had Lead enough fix'd at its lower End to make the Ball just as heavy as at first. Now having suspended the Ball as before, and repeating the Experiment, it did not recoil near to the same Height, tho' it had the same Quantity of Matter as before, its percutient Surface the same, and the Shell was half an Inch thick. Afterwards I made use of a Ball of twice the Weight of this hollow one which was solid, and having observ'd what Degree it recoil'd to, I shut up my hollow Ball with another Ivory Plug, which had so much more Lead at bottom as to make it twice as heavy as before; but upon Trial it did not recoil so high as the solid Ball used last, tho' it weigh'd as much.

If there be an immoveable, but elastick Obstacle, as O M B *, and a perfectly hard Ball, as M (that is, such an one as cannot be dented in) strikes against it, the Obstacle must yield, and its Surface will change its Figure,

* Plate 1. Fig. 4.

Figure, as for Example from O M B to O *m* B; but by reſtoring it Lect. VI.
ſelf, it will drive the Ball back again. But if the Obſtacle be perfectly hard, and only the Ball elaſtick, as in *Fig.* 5. then only the Ball will be dented or flatten'd as at *n n*; but the Ball muſt recoil as before. Then if both the Bodies be elaſtick, the Recoil of the Ball will be as before; for as the ſame Force is ſuppoſed to cauſe the bending in of the Surface in one or in both Bodies, there will (by the 3d Law of Nature) be exactly the ſame Force of Reſtitution. Plate I. Fig. 5.

11. Now becauſe the Change of Figure in Bodies of quick Elaſticity is not viſible, ſome People have imagin'd Balls of Ivory, Steel, Glaſs, or Amber, and Diamonds and other precious Stones, not to be elaſtick, conſidering them only as hard Bodies; whilſt they have allow'd long Plates of Steel, ſuch as the Blades of cutting Inſtruments, Muſical Strings, and long Pieces of Wood or Whale-Bone, Balls of Wool, Bladders or Foot-Balls filled with Air to be elaſtick, becauſe their Change of Figure is viſible: But the greateſt Degrees of Elaſticity do not conſiſt in the viſible yielding in and Reſilition of the Parts, but in their perfect Reſtitution, however difficult it be to ſee their Action. Yet it may be eaſily perceived that their Figure has been changed, by the following Experiments.

Experiment 4. *Plate* 1. *Fig.* 6.

Take two Ivory Balls, of equal or unequal Diameters, as M, *m*, ſuſpended by Strings of any length as M S, *m s*, one of which has part of its Surface as *n n* painted with ſome Colour freſh laid on. Having ſuſpended them both, bring the unpainted Ball as M to the painted one, and it will receive from the other a little Spot of Paint on its Surface, which will be irregular, becauſe the Hand can't hold M ſteadily againſt *m*. But by letting M fall againſt *m*, the Spot upon M ought to be much leſs, if its Surface did not change its Figure, becauſe the Contact then would be leſs. Now, upon making the Experiment by a Blow, the Surface of each Ball is flatten'd at *nn*, and each Ball has a circular Mark upon it as *n* at *Fig.* 7. the one ſhewn by the Paint ſtruck off, and the other by the Paint receiv'd. The ſame will happen if you let the Ball fall upon a Block or Lump of Ivory, Steel, or Glaſs as O B, whoſe upper Surface is horizontal and ſmooth; for after the Blow the Spot *n n* will be very apparent, and the larger according as the Stroke has been greater. Plate I. Fig. 6. Plate I. Fig. 7. Plate I. Fig. 8.

Experiment 5. *Plate* 1. *Fig.* 9.

If the Block or the Ball be of Glaſs, the Inſide may be broken whilſt the Surface remains entire; as will be ſeen when the Bodies have no Plate I. Fig. 9.

Paint

Lect. VI. Paint upon them, the broken Places *n*, *n*, *n*, appearing within the Bodies like Half-Moons, whilſt drawing one's Finger-Nail over the Surface, no Crack or Unevenneſs is to be felt. The Glaſs indeed is become ſo much weaker on the Surface over the Crack *n*, *n*, *&c.* that a Blow or two of the ſame Force, as firſt made the Crack, will break out the Piece. N. B. *Glaſs Bodies may receive the Crack by a Stroke of a Hammer on any other hard Body as well as Glaſs.* Why the Glaſs is ſooner broken within than at the Surface; and why that broken Part becomes viſible and ſhining, we ſhall ſhew in the Notes.*

* Ann. 2.

Plate 1. Fig. 1.

12. The Vibrations of the String A B (*Fig.* 1.) communicate a vibrating Motion to the Air, and thereby produce a Sound; this Sound being the more acute, or the Note the higher, the ſhorter the String is (ſuppoſing an equal Degree of Tenſion) becauſe the Vibrations will be quicker, more of them being produced in the ſame time, as the ſhorteſt Pendulums move quickeſt, Gravity acting upon them as Elaſticity does upon Strings. The Surfaces and *Strata* of Glaſs Balls, and other ſuch elaſtick Bodies, do alſo give a Sound by their vibrating Motion, and the more acute or tingling the Sound is, the more perfect is the Elaſticity, as proceeding from the Vibrations of ſhorter Parts of the Surface and ſhorter *Strata.* Glaſs has the moſt tingling Sound of any Body we know, and accordingly we find by ſeveral Experiments that it is the moſt elaſtick.

The Vibrations of Glaſs may yet be made more ſenſible by the following Experiment.

Experiment 6. *Pl.* 1. *Fig.* 10.

Plate 1. Fig. 10.

A B E C D is a Glaſs Bell, or Air-Pump Receiver, fix'd with Cement by its upper End or Knob A, to the horizontal Board *p p*, ſupported by the Pillars P *p*, P *p*, of the wooden Frame P S *p* A *p* P, in ſuch manner that the Bell touches the Wood only at top, and that it may tremble freely when made to ſound by ſtriking its lower Circle or Mouth B C. S is a braſs Screw going thro' one of the Pillars, ſo that its End may be brought as near as you pleaſe to the Bell before you ſtrike it. Then ſtriking the Bell with any thing to make it ſound any where between B and C, you may both ſee and hear the Lip or Brim of the Bell ſtrike ſeveral times againſt B the end of the Screw S B; and this Succeſſion of Strokes (ſtill weaker and weaker) will continue the longer, if you follow the Edge of the Bell with the end of the Screw B, by gently ſcrewing it forward as the vibrating of the Bell is ceaſing. This Motion of the lower Part of the Bell ſeems to be a continual Change of the circular

circular Mouth to an Oval and back again, the Points B, C, and the Points D, E, alternately approaching towards one another: And a Person of Credit told me, that he had several times stuck a stiff Wheat-straw across the bottom of a great Bell, of which the Clapper was taken out; which Straw, after a Stroke on the Bell, would drop out as the Figure of the Bell chang'd in sounding. Lect. VI.

If a Finger be applied to the Outside of the Glass Bell, the Vibrations and the Sound will quickly, but gradually, be destroy'd; and so much the sooner, if you apply two or three Fingers, and almost instantly if you apply your whole Hand. The same will happen to a Bell of Metal: but it is observable here, that the Vibrations, whereby the Edge of the Bell strikes the Screw, do not cease so soon as the Sound; because you may hear the Edge of the Bell rattle against the Screw, after the proper Sound of the Bell is heard no more.

Experiment 7.

If you pinch the Edge of the Bell with your Finger and Thumb-Nail, and draw them away suddenly in the Direction A E, you will thereby excite the same Sound in the Bell, as when it was struck at E, but there will be no sensible Alteration of the Figure of the Bell, or perceptible Advance to, or Removal from, the Screw S B, no stroke being made against it. Hence it appears that there are two sorts of Vibrations in elastick Bodies *, one sort extremely quick, which is most properly productive of Sounds, and is by some called a Tremor of the small Parts; and another more slow, whereby elastick Bodies restore themselves to their Figure and Position, and repel Bodies that have press'd or struck against them. These generally act together, but not sensibly always; for a stretch'd String as A B (*Fig.* 1.) may restore it self, and repel the Ball that has driven it into the Position A C B, without producing any Sound; and the same String may produce a Sound, without having its Vibrations large enough to be visible. But this we may be assured of, that whatever Body we perceive to have Resilition when struck, may have its Elasticity excited so as to produce Sound, and whatever Body gives a Sound, is capable of repelling or being repell'd by other Bodies that strike it.

* Ann. 3.

Plate 1. Fig. 1.

13. The bending in of the *Strata* of elastick Bodies, would be a sufficient Proof of a *Vacuum*, if there was no other. For without void Spaces within the Body for the Particles displaced by the Blow to retire to, and return from, there could be no Elasticity. This may be further illustrated by the following Experiment.

Lect. VI.

EXPERIMENT 8. *Plate* I. *Fig.* II.

Plate I. Fig. II.

TAKE two thin Pieces of Money (for Example two Sixpences) not bent and something worn, as A, B; so that when they are thrown against the flat Board A B D, they will give a sharp Sound, each of them as near as can be got of the same Note. Then rub one of them with Quicksilver, so that it may visibly imbibe it, and you will find when you strike it against the Board, and compare it with the other Piece, that its Sound is grown dull, as if it was changed into a Piece of Lead. This seems to arise from filling some of the Pores into which the elastick *Strata* used to retire by the Blow, and hereby hindering their more perfect Vibrations. For if you hold the Piece of Money between the End of a red-hot pair of Tongs to cause the Mercury to evaporate, the Piece of Money will recover its tingling Sound, provided you stay till it is thoroughly cold, because when hot it is not quite so sonorous by reason of its Softness.

Now if there were Bodies that had no Vacuities for the Particles of their *Strata* to be driven into, and the Cohesion of their Parts were so strong that a Blow could not separate them, those would be *perfectly hard* Bodies. And in the Congress of such Bodies, there being no Alteration made in their Surface, there could be no cause of their separating again after the Blow; but they must either stand still together, or go on towards that side where the greatest Quantity of Motion was directed.

14. AGAIN, if we still suppose Bodies without Vacuities, but their Parts to have so little Cohesion as easily to slide from one another, and only to make them stay in their Places, when they have been push'd over one another, those Bodies would be *perfectly soft*. They might also be called *perfectly soft*, tho' they were full of Pores, provided there was no Substance in those Pores to repel the Particles again when driven into them, nor force in the Particles themselves to repel each other. These Bodies also in their Congress would not separate again after the Blow; because tho' they would be flatten'd or dented in, they could not part again, there having been supposed in them no Force capable of throwing them back from each other.

BODIES therefore *perfectly hard*, and Bodies *perfectly soft*, would, in their Congress, produce the same Effects; especially with regard to their common Center of Gravity, which would be affected in the same manner in

in hard and in soft Bodies. And this would happen also if hard Bodies came against soft ones, and *vice versâ*. Lect. VI.

Now tho' there are no Bodies perfectly hard, since even Diamonds, whose Parts cohere the strongest of any thing we know, have so much Velocity as to be highly elastick; and tho' the softest Bodies that can hold together, as Balls of soft Clay, have Air in them enough to give them Elasticity; yet, when we wou'd confirm by Experiments what would happen to Bodies without Elasticity in their Congress, (whether *hard* or *soft*) we may make use of soft Clay Balls, making Allowance for the little Elasticity they have left, or what they want of perfect *Softness*.

So likewise in the Congress of elastick Bodies, tho' we make Experiments with Balls of Steel, Marble, Ivory, Glass, &c. which are not perfectly elastick, we can easily come at true Conclusions, by making proper Allowances for the Defect of Elasticity.

15. In order to give a clear and full Account of all that relates to the Congress of Bodies, we shall first give general Rules relating to all Bodies that meet, overtake, or strike one another in any Manner, whether they have any Elasticity or not: Then we shall consider what must happen to Bodies which have no Elasticity, as *hard* or *soft* Bodies: And lastly, we shall examine the Congress of elastick Bodies.

These Rules are all Corollaries of Sir Isaac Newton'*s third Law of Motion.*

Rule I.

16. *The Quantity of Motion, which is collected by taking the Sum of the Motions directed towards the same Parts, and the Difference of those that are directed towards contrary Parts, suffers no Change from the Action of Bodies among themselves.*

Corollary I.

From hence it follows, that if one Body strikes against another, which is either at Rest, or moves more slowly according to the same Direction, the Sum of the Motions in the two Bodies towards the same Parts will be the same after the Stroke as before *.

* Ann. 4.

Corollary 2.

It also follows, that if two Bodies moving in contrary Directions meet one another full, the Sum of the Motions towards the same Parts (which is the Difference of the Motions towards contrary Parts) will continue the

Lect. VI. the same both before and after the Meeting of these Bodies. *See these two Consequences further explain'd and illustrated in the Notes* *.

* Ann. 5.

RULE 2.

17. *The common Center of Gravity of two or more Bodies, does not alter its State of Motion or Rest by the Actions of the Bodies among themselves; and therefore the common Center of Gravity of all Bodies acting upon each other, (excluding outward Actions and Impediments) is either at Rest, or moves uniformly in a right Line.*

FOR the better understanding of this, read what has been said in the second Lecture and its Notes; and also four remarkable Cases of this Truth demonstrated in the Notes to this Lecture *.

* Ann. 6.

RULE 3.

18. *The Motions of Bodies included in a given Space are the same among themselves, whether that Space is at Rest, or moves uniformly forwards in a right Line, without any circular Motion.*

FOR the Differences of the Motions tending towards the contrary Parts, and the Sum of those that tend towards the same Parts, are at first (by Supposition) in both Cases the same; and it is from those Sums and Differences that the Collisions and Impulses do arise with which the Bodies mutually impinge upon one another. Wherefore (by the second Law of Motion) the Effects of those Collisions will be equal in both Cases; and therefore the mutual Motions of the Bodies among themselves in the one case, will remain equal to the mutual Motions of the Bodies among themselves in the other. A clear Proof of which we have from the Experiment of *a Ship; in which the Motions of all the Bodies that it contains happen after the same manner, whether the Ship is at rest, or is carried uniformly forward in a right Line.*

DEFINITION.

19. *One Body is said to* strike, *or* impinge against *another* directly, *when the right Line along which it moves, being drawn thro' the Center of Gravity of the impinging Body and the Point of Contact, is perpendicular to the Surface of the Body against which the percutient or impinging Body strikes: or if they don't strike in a Point, but in a Line or a Surface; still the Stroke will be* direct, *if the Line or Direction of Motion above-mention'd* be *perpendicular to this last-mention'd Line, or Surface of Contact.*

RULE

Rule 4.

20. *If two Bodies, whether equal or unequal, are carried towards the same Parts, with Velocities any how equal or unequal, the Sum of the Motions of the two Bodies is equal to the Motion that wou'd arise by the Sum of the Motions of the two Bodies, if each of them was mov'd with the same Velocity as their common Center of Gravity moves with.*

See this particularly demonstrated in the Notes *. * Ann. 7.

Rule 5.

21. *If two Bodies are carried towards contrary Parts, the Difference of the Motions towards contrary Parts, or (what is the same) the Sum of the Motions towards the same Parts, will be equal to the Motion, (that is, to the Sum of the Motions) that wou'd be produc'd if both Bodies moving the same way, or towards the same Parts, each of them was carried with the same Velocity as the common Center of Gravity.*

See this further explain'd and demonstrated in the Notes *. * Ann. 8.

Concerning the Congress of Bodies that have no Elasticity.

Rule 6.

22. *If a Body without Elasticity comes directly against another Body, which is also void of Elasticity; whether this last Body be at rest, or whether it be moving more slowly the same way; or lastly, if it be moving in a contrary Direction, and the Motions are unequal, the two Bodies will go together after the Stroke along with the common Center of Gravity. Plate* I. *Fig.* 12.

A and B are the two Bodies. Let A strike the Body B directly, which Body B we will suppose at rest, or moving the same way as A, but slower, or towards contrary Parts with less Motion; I say, that after the Stroke both Bodies will move together with the same Velocity along with the common Center of Gravity. For since (by the second Law) the Body B is not hinder'd by other circum-ambient Bodies, it will be mov'd by the Force which the Body A impresses on it towards those Parts which the Forces are directed to; and it will also move jointly with the Body A: For first, it cannot move slower, by reason of the following Body A; then it cannot move faster, because (by the Supposition) there is no other Cause of such a Motion besides the impellent Body A; since all other Things, as an elastick Force, and an ambient Fluid are suppos'd to do nothing: Therefore after the Stroke both Bodies will be join'd, and

Plate I. Fig. 12.

Lect. VI. move along with their common Center of Gravity. *Which was to be demonstrated.*

Corollary.

23. If the Bodies are suppos'd to come together at D, as the Velocities of the Things whose Motions we consider are the Spaces describ'd in the same Time, the Velocities of the Body A, of the Body B, and of the Center of Gravity C, are before the Stroke as the right Lines A D, B D, C D, respectively; for those are the Lengths which are run thro' in the same Time.

Problem I.

How to determine what the Motion of Bodies that have no Elasticity will be after their striking one another directly. Plate I. *Fig.* 13.

Plate I. Fig. 13.

In order to solve all the Cases of this Problem, which we shall do by six Figures, we shall use the same Construction; that is, we shall make the same Letters signify the same thing in each Figure. Let there be two Bodies A and B, whose Center of Gravity is C, and let us suppose the Bodies to concur in D; the Velocities of the Body A, of the Body B, and of the common Center of Gravity C, will (by the foregoing Corollary) be as the right Lines A D, B D, and C D respectively:- Now let D E be equal to D C, and it will represent the Velocity of the Bodies after the Stroke: that is, the Velocity of the Body A before the Stroke will be to its Velocity after the Stroke, as A D to D E; and the Velocity of the Body B before the Stroke will be to its Velocity after the Stroke, as B D to D E; for (by Rule 6.) the Bodies A and B, after the Stroke, will go on together along with the common Center of Gravity: But (by the second Rule) the Velocity of the common Center of Gravity will remain the same both before and after the Stroke, and go on the same way; therefore if C D represents its Velocity before the Stroke, D E equal to C D will represent its Velocity after the Stroke; and therefore D E will also express the Velocity of the Bodies A and B, which go along with the Center C after the Stroke. *Which was to be shewn.*

Corollary I.

25. If the Body B be at rest, the Point B will coincide with the Point D, as in the 13th Figure: and because B is to A as A C to B C or D E*, by Composition A+B: (that is the Sum of the Bodies A and B) will be to the Body A:: as A B or A D: to D E. That is, *the Velocity of the Body*

* L. 2. N° 39.

A

A before the Stroke, is to its Velocity after the Stroke, as the Sum of the Bodies to the impingent Body A. Lect. VI.

EXAMPLE 1. *Fig.* 13.

If A be equal to B, and B is at reſt, A+B: will be to A as 2 to 1, therefore the Velocity of the impinging Body will, before the Stroke, be the Double of what it will be afterwards. Plate 1. Fig. 13.

EXAMPLE 2. *Fig.* 14.

If A is to B as 1 to 9, then will A+B: be to A as 10 to 1; therefore the Velocity after the Stroke will only be the 10th Part of what it was before the Stroke. Plate 1. Fig. 14.

EXAMPLE 3. *Fig.* 15.

If the Body B be infinitely greater than A, the Velocity of A after the Stroke will be infinitely ſmall, that is, will be none at all; for in that Caſe A vaniſhes in reſpect of A+B, and therefore the Velocity of the Body A after the Stroke will alſo vaniſh; that is, if a Body ſtrikes againſt an immoveable Obſtacle, after the Stroke it will be at reſt. Plate 1. Fig. 15.

EXAMPLE 4. *Fig.* 15.

If the Bodies A and B are equal, and B moves in the ſame Direction, but ſlower, D E or C D will be equal to half A B added to B D, or half the Sum of A B, and twice B D, or half the Sum of A D and B D; that is, the Velocity after the Stroke will be half the Sum of the former Velocities. Or to give a View of it in the Algebraical Expreſſion, $DE = \frac{AB}{2} + BD = \frac{AB + 2BD}{2}$.

EXAMPLE 5. *Fig.* 16.

If the Bodies move towards contrary Parts with equal Degrees of Motion, the Point D will coincide with C, (as a Conſequence of the ſecond Rule) and C D and D E will be equal to nothing; that is, both Bodies will be at reſt after the Stroke; as alſo their Center of Gravity is before the Stroke whilſt they are moving towards one another *. Plate 1. Fig. 16.

* L. 2. N° 32.

COROLLARY 2.

This ſhews that Law of Motion of *Deſcartes* to be falſe, whereby he aſſerts, *that the ſame Quantity of Motion is always preſerv'd in the World*; becauſe here we find, that Bodies which have no Elaſticity

moving

Lect. VI. moving contrarywiſe, by running againſt each other with equal Quantities of Motion, deſtroy each other's Motions.

EXAMPLE 6. *Fig.* 17.

Plate 1. Fig. 17. IF equal Bodies go towards contrary Parts with unequal Quantities of Motion, their Velocity after the Stroke will be half the Difference of their former Velocities——or it may, with regard to the Figure, be expreſs'd Algebraically thus, DE or CB will be equal to $CB - BD = \frac{AB}{2} - BD = \frac{AB - 2BD}{2}$.

NB. *A general Solution of this Problem is given by a Calculation in the Notes.* *

COROLLARY 3.

*Ann. 9. SINCE the Velocity of the Body A before the Impulſe was AD, and after the Impulſe its Velocity was as CD, the Velocity loſt will be AC, and therefore the Motion loſt by the Stroke $A \times AC$.

RULE 7.

26. *If a Body in motion ſtrikes directly againſt another, whether that other be in motion or at reſt; the Magnitude of the Blow is proportional to the Momentum which is loſt at the Stroke in the ſtrongeſt Body, if one be ſtronger (that is, has more Motion) than the other.*

For if you ſuppoſe the ſtrongeſt Body (if there be one) or either of them, if their *Momenta* are equal, to be the percutient Body, and the other the Body ſtruck; the Magnitude of the Blow will be equal to the Force which the percutient Body impreſſes on the Body ſtruck: but that Force which is impreſs'd on this laſt by the Percutient, is loſt (by the third Law of Motion;) therefore the Motion loſt in the percutient Body will be proportional to the Force impreſs'd on the Body ſtruck, and conſequently to the Magnitude of the Blow. *Which was to be proved.*

COROLLARY.

27. WHERE percutient Bodies loſe equal *Momenta*, the Magnitudes of the Strokes will be equal.

RULE 8. *Plate* 1. *Fig.* 18.

28. *If a given Body ſtrikes directly againſt another given Body, the Magnitude of the Blow will always be proportionable to the Velocity of the Percutient.*

LET the given Body A, with a Velocity expreſs'd by A B *, ſtrike another given Body B, which is at reſt; then again let the ſame Body A, with another Degree of Velocity as D E ſtrike the other Body B ſtill ſuppoſed at reſt: that is, let A B: be to D E : : as the former Velocity : to the laſt, and let the Diſtance of the Bodies be as A B, D E; (for whatever Diſtance there is between them, in the Beginning of the Motion, it will be the ſame thing as to the greatneſs of the Blow;) and let the common Center of Gravity be at C in the firſt Situation, and at G in the ſecond. When the Body A is moved with the Velocity A B, C B will be its Velocity after the Stroke; and ſince before the Stroke the Motion was A × A B (that is, A multiplied into A B), the Motion after the Stroke will be A × C B; and the Motion loſt will be A × A C. In the ſame manner, if this percutient Body be moved with the Velocity D E, the Motion loſt will be A × D G, and therefore the Magnitude of the Blow with the Velocity A B will be to the Magnitude of the Blow with the Velocity D E, as A × A C to A × D G, or as A C : to D G. Now becauſe A C : is to B C : : as B : to A, therefore will A C : be to A C + B C (that is A B) : : as B : to A + B; and likewiſe will B : be to A + B : : as D G : to D E; and therefore will A C : be to A B : : as D G : is to D E; when (by Permutation of Proportion) A C : will be to D G : : as A B : to D E; that is, the Magnitude of the Blow with the Velocity A B : will be to the Magnitude of the Blow with the Velocity D E : : as the Velocity A B : to the Velocity D E. *Which was to be proved.*

* Plate 1. Fig. 18.

COROLLARY. *Plate* 1. *Fig.* 19.

IF the Body A runs againſt the Body B †, the Motion loſt is A × A C; but if the Body B runs againſt A with the ſame Velocity, then the Motion loſt is B × B C; but becauſe then B C muſt be to A C as A to B, then will A × A C be equal to B × B C, and conſequently the ſame Quantity of Motion will be loſt by the Blow, whether B impinges on A with a given Velocity, or A impinges on B with the ſame Velocity; and therefore in both Caſes the Magnitude of the Blow will be the ſame.

† Plate 1. Fig. 19.

RULE 9. *Plate* 1. *Fig.* 20.

29. *If one Body directly ſtrikes another which is moving ſlower along the ſame right Line; the Magnitude of the Blow will be the ſame, as if the antecedent Body ſhou'd be at reſt, and the following Body ſhou'd be carried againſt it with the Difference of their Velocities.*

Lect. VI. * Plate 1. Fig. 20.

LET A and B* be two Bodies going the ſame way, whoſe common Center of Gravity is C; and let the Bodies be ſuppoſed to come together in D: it is plain from what has been ſaid before, that the Velocities of the Bodies before the Impulſe are as the right Lines A D, B D, and therefore the Difference of thoſe Velocities will be as A B; but as the Velocities of both Bodies after the Stroke will be expreſs'd by C D, therefore the Motion loſt in the Body A, will be A x A C. Now if the Body A ſhou'd ſtrike againſt the Body B at Reſt with the Velocity AB, its Velocity after the Stroke would only be equal to C B, and the Motion loſt would be A x A B. Therefore ſince the Percutient in each Caſe loſes the ſame Quantity of Motion, the Magnitude of the Blow will always be the ſame.

RULE 10. *Plate* 1. *Fig.* 21.

Plate 1. Fig. 21.

30. *If two Bodies meet one another with contrary Motions, the Magnitude of the Blow will be the ſame as if one of them was at reſt, and the other came upon it with the Sum of their Velocities.*

LET the two Bodies A and B be carried towards contrary Parts, their common Center of Gravity being at C, and D be the Point in which they meet: it is plain that the Velocities of the Bodies A and B are as the right Lines A D, B D; and therefore let the Sum of their Velocities be expreſs'd by A B: C D will expreſs their Velocities after the Stroke, and therefore the Motion loſt in the Body A will be A x A C. But if A ſhould with the Velocity A B ſtrike B at reſt, the Velocity after the Stroke would be as C B, and the Motion loſt A x A C. Therefore as there is the ſame Quantity of Motion loſt in both Caſes, ſo likewiſe the Magnitude of the Blow will be the ſame. *Which was to be proved.*

COROLLARY 1.

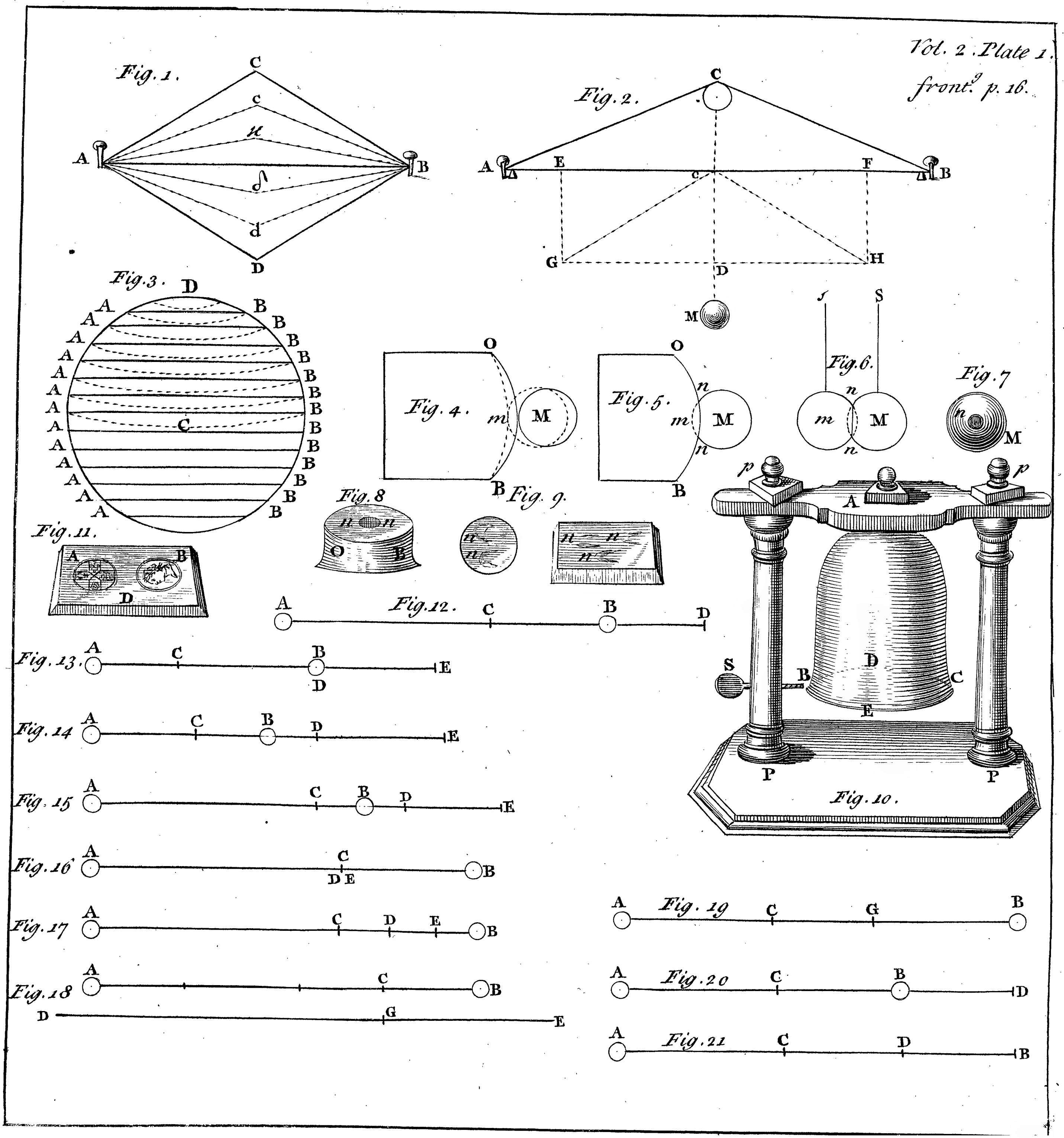
IF therefore there remains the ſame Sum of Velocities, that is, the reſpective Velocity of the Bodies A and B, whereby they come towards one another, whatever be their Difference of Velocity, or however that Velocity be divided between the concurrent Bodies, the Magnitude of the Blow will always be the ſame.

COROLLARY 2.

THEREFORE the Magnitude of the Blow in given Bodies is always proportional to their Velocities reſpectively.

Co-

Vol. 2. Plate 1.
front.[9] p. 16.



COROLLARY 3.

HENCE also may be deduced what we have said in our third Rule, and its Explication, *viz.* That the Motions of Bodies included in any Space, whether that Space be at rest, or be moved uniformly in a direct Line, are always the same; for the Differences of Velocities whereby Bodies tend the same way, and the Sums of the Velocities whereby they tend towards contrary Parts, are the same, whether the Space in which the Bodies are contain'd be at rest, or whether it be moved uniformly in right Lines; therefore the Magnitudes of the Blows being always proportionable to them, must be the same in both Cases. Hence, as we said before, all the Motions in a Ship are in the same Condition, whether the Ship be at rest, or moving forwards uniformly. Thus also all the Phænomena of Projectiles and Percussions happen with us upon the Earth, whether we are carried along with the Earth by the common Motion, or whether the Earth stand still, as some imagine. Therefore the Objections brought against the Motion of the Earth, from what the Objectors supposed must happen to Projectiles, by reason of its Motion, were, from what we have said here, of no force, as proving nothing one way or other.

31. EXPERIMENTS *made with soft Clay Balls, for further illustrating what has been said before, concerning the* Congress *of* Bodies *which have* no Elasticity.

NB. *The Machine to be used for the Congress of Bodies, (whether elastick or not elastick) is the same that is described in the first Volume* Page 371. Lecture 5. N° 60. *for making Experiments on pendulous Bodies; only with this Improvement,* viz. *that the Angle* DEC *must be large enough for the similar Arcs at bottom graduated on either side to contain a sufficient Number of Degrees; the Machine also must be made of two triangular Pieces, which join in a perpendicular Plane or Section between the Lines* a A *and* b B, *that they may be drawn a little way from each other, when one or both the Balls are large, for the Center of the Ball to be always against the Beginning of the Division* o ι, *from which we reckon; and the Pins* a *and* b *must be long enough for the biggest Balls to hang so forward, as not to touch the Board in their Motion. There must be also a Contrivance of an horizontal Piece to fix on at* E b a, *to carry more Pins than two, when we have a greater Number of Balls to hang on.*

Lect. VI. TAKE a couple of Cylinders of Lead, each two Inches in Diameter, and about an Inch and an half high, and let a hemiſpherical Cavity be turn'd in each of them, ſo that when they are laid upon one another, they may contain an hollow Sphere of an Inch and an half Diameter. Let two places of the Edge of this Cup of about a quarter of a Circle each, be ſlanted off, as at *a*, *b*. A in the firſt Figure *Plate* 2. repreſents the hemiſpherical Cavity ſeen horizontally, B one of the Cylinders ſet upright, and CD the two Cylinders ſet upon one another. This Machine ſerves to make Clay Balls which weigh two Ounces *Averdupoids*, the Cavity being firſt well oiled that the Balls may come out eaſily. A little Stick of about half an Inch long and $\frac{1}{4}$ of an Inch Diameter, muſt have a String of about ſix Inches, with a Loop at one end, tied to it in the middle; and this Stick being put within the Ball, one end of the String muſt go out of the Cylinder at the thin Notch *a* as *m*, and the other end with the Loop muſt go out at right Angles to the former at *n*, whilſt the Cylinders are preſs'd hard together, and form the Clay Balls ſmooth by means of the Pins and Holes as *c*, *d*, *e*, in the Edges which receive one another. A Clay Ball thus made, may be ſuſpended at a long String to make a Pendulum of for Congreſs, whilſt the little String *m* coming out at its ſide, ſerves to hold it by before we let it go, without altering its Shape; for if we make the Balls of very ſoft Clay, they will have ſo little Elaſticity, that it may be eaſily allow'd for. See a Clay Ball finiſh'd at E. Another Pair of Leaden Cylinders whoſe Cavity is of three Inches Diameter, will ſerve to make Balls whoſe Weight is 8 Ounces each: As for a Ball of 18 Ounces which we uſe, it may be made exactly enough with the Hand, firſt weighing the Clay.

Plate 2. Fig. 1.

THE Figures that repreſent the Experiments, by the ſhaded Balls, ſhew the ſtate they are in before the Congreſs, the pointed Circles ſhew where the Stroke is made; and the Circles made with Lines a little longer than Points, ſhew where the Bodies are after the Stroke; and the Darts drawn in the Balls, ſhew which way they move. *This way of drawing the Figures I have taken from Mr. Profeſſor* s'Graveſande, *who was always very curious in his Figures: And indeed in the Congreſs of Bodies he has taken ſo much Pains in endeavouring to reconcile* Phænomena *with the new Opinion concerning the Force of Bodies, that it is pity that he did not ſucceed. For however it may be agreeable to Forces where Time is not conſider'd, pendulous Bodies (while they keep the ſame length) have all their Vibrations iſochronal, in which caſe their ſhock will hardly agree with the Maſs multiplied into the Square of the Velocity, and the known Laws of Congreſs explain'd by Sir* Iſaac Newton, *as I ſhall ſhew in the Notes.* *

*Ann. 10.

EXPE-

EXPERIMENT 1. *Plate* 2. *Fig.* 2.

32. THE Clay Ball A, weighing two Ounces, with the Velocity 16, comes upon B of two Ounces alſo which is at reſt, and after the Stroke they both go on together, with half the Velocity of A. *See Example the firſt.*

EXPERIMENT 2. *Plate* 2. *Fig.* 3.

THE ſame Body A with the ſame Velocity overtakes B, which moves the ſame way with only 8 Degrees of Velocity. They ſtrike at the loweſt Place, and after the Stroke they both go on together with half the Sum of the Velocities, which they had before the Stroke. *See Example fourth.*

EXPERIMENT 3. *Plate* 2. *Fig.* 4.

A and B ſtill equal meet in contrary Directions, each with the ſame Velocity of 14, and after the Stroke they deſtroy each other's Motions and ſtick together. *See Example the fifth.*

EXPERIMENT 4. *Plate* 2. *Fig.* 5.

A and B (ſtill of two Ounces each) ſet out from contrary Parts towards one another, A with 18 Degrees of Velocity, and B with 8: after the Stroke they both go together that way to which the greater Quantity of Motion tends, with half the Difference of the Velocity before the Stroke. *See Example the ſixth.*

EXPERIMENT 5. *Plate* 2. *Fig.* 6.

Let a Clay Ball 3 Inches Diameter weighing 8 Ounces (here mark'd B) with a Velocity of 5 Degrees, come with a contrary Motion againſt A, which meets it with 20 Degrees of Velocity, and the two Bodies will ſtand ſtill after the Stroke. *This is another Inſtance of the fifth Example.*

EXPERIMENT 6. *Plate* 2. *Fig.* 7.

NOW A of two Ounces with 20 Degrees of Velocity comes upon B which is at reſt, and now weighs 18 Ounces. After the Stroke they will both go on with the Velocity Two; which Velocity in unequal Bodies (one of which is at reſt) will always be found by dividing the *Momentum* of the percutient Body before the Stroke, by the Maſs of the two Bodies after the Stroke. *See Example the ſecond.*

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EXPERIMENT 7. *Plate* 2. *Fig*. 8.

THE Ball A of 2 Ounces with the Velocity 10, comes upon the Ball B 8, which is at rest: after the Stroke, both go on together with the Velocity of Two, found by dividing the *Momentum* by the Bodies as before, *according to the said second Example*.

EXPERIMENT 8. *Plate* 2. *Fig*. 9.

THE Ball A of 2 Ounces with 12 Degrees of Velocity is met by B of 8 Ounces and 8 Degrees of Velocity, and after the Stroke both Bodies go together towards A with the Velocity 4. To find this Velocity in unequal Bodies, when they come against each other in contrary Directions, we must subtract the least Motion from the greatest before the Stroke, and divide the Remainder by the Sum of the Bodies, for the Velocity after the Stroke. But if the Bodies go the same way, you must add the Motions of the Bodies before the Stroke, and divide that Sum by the Mass of the Bodies: because (by Rule the first) the Sum of the Motions which Bodies have towards the same Parts, or the Difference which they have towards contrary Parts, is not altered by the Stroke; but is the same both before and after the Stroke. *

* See the Notes.

33. CONCERNING *the* CONGRESS *of elastick Bodies*; for which a proper Allowance may always be made as if their Elasticity were perfect, as will be shewn before we quit this Subject.

RULE II.

34. *If two Bodies perfectly elastick strike against each other, their relative Velocity will remain the same before and after the Stroke: that is, Bodies perfectly elastick, will recede from one another after the Stroke with the same Velocity that they came together.*

FOR (by the *Coroll.* of *Rule* 8.) the compressive Force, or the Magnitude of the Stroke in given Bodies, arises from the relative Velocity, and is proportionable to it; and, as we have already shewn, Bodies perfectly elastick do restore themselves to their former Figure, with the same Force that they were compress'd; that is, the restitutive is equal to the compressive Force, and therefore acts just as strongly as the Force by which the Bodies came together before the Stroke: But by that restitutive Force the Bodies are made to rebound from one another; whence this Force acting upon the same Bodies, will produce a relative Velocity equal to that which they had before; that is, will make the Bodies recede

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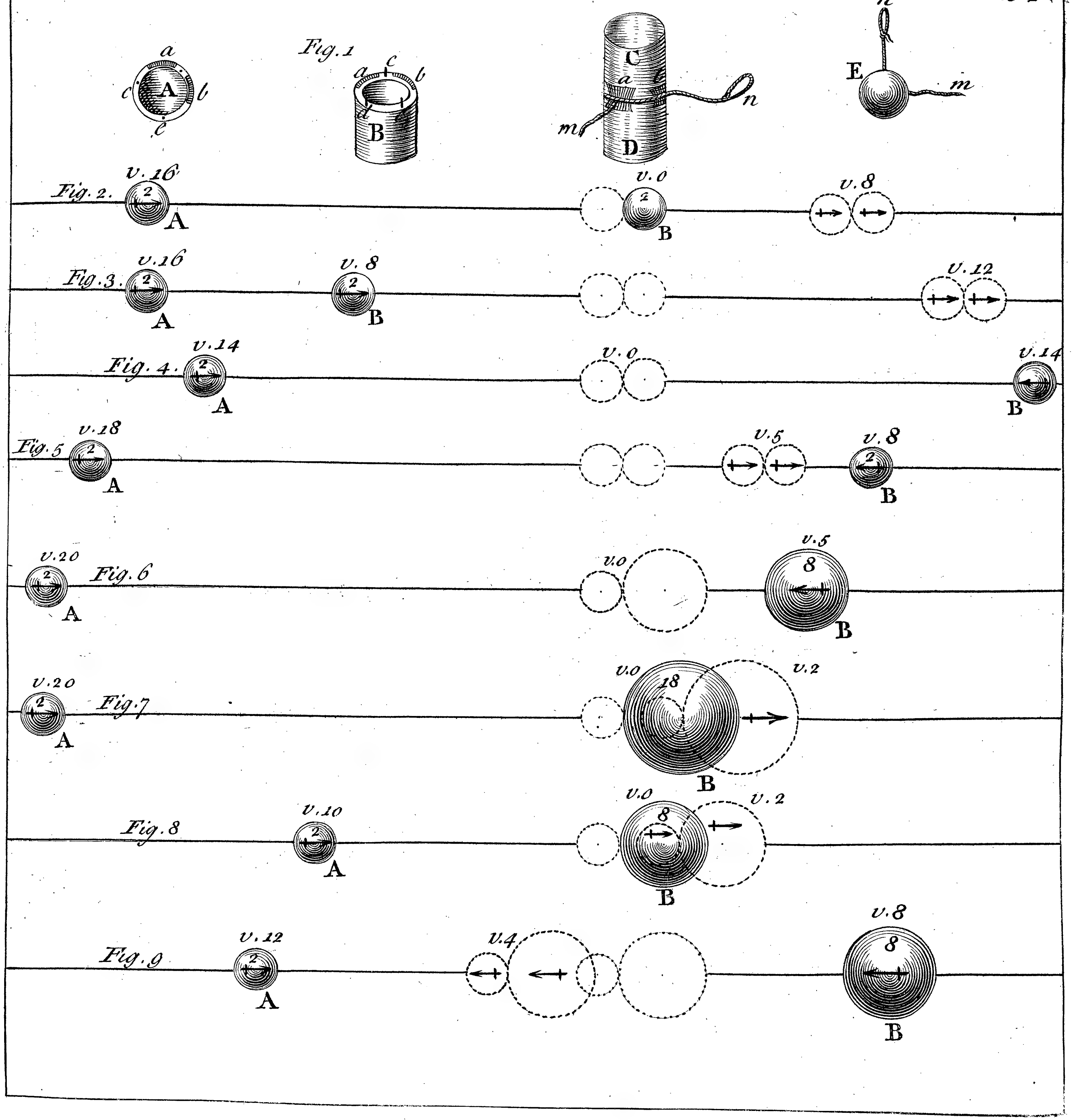
Plate 2.



recede from one another with the ſame Velocity that they acceded before. *Which was to be demonſtrated.* Lect. VI.

Corollary.

Therefore, taking equal Times before and after the Stroke, the Diſtances of the Bodies from one another will be equal, and therefore at the ſame Times the Diſtances of the Bodies from the common Center of Gravity will alſo be equal.

Hence may be determin'd the Rules of the Congreſs of perfectly elaſtick Bodies, *in the following Manner.*

Problem 2.

35. *How to determine the Rules of Congreſs in perfectly elaſtick Bodies ſtriking one another directly.*

All the Caſes of this Problem may be conſtructed in the ſame manner; as may be ſeen in the firſt eleven Figures of Plate the third. Plate 3. Fig. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11.

Let A and B be two Bodies perfectly elaſtick, whoſe common Center of Gravity is C, and let us ſuppoſe that the Bodies come together at C, and let CE be equal to CD. I ſay, that after the Stroke, the right Line EA will expreſs the Velocity of the Body A from E towards A, and the right Line EB the Velocity of the Body B from E towards B.

Demonstration.

Since (*by Rule* 2.) the common Center of Gravity of Bodies (both before and after the Stroke) does always go forward uniformly with the ſame Velocity; in a Time equal to that in which the Body A runs the length AD, or the Center of Gravity runs the length CD, the ſaid Center of Gravity C will after the Stroke run the length DK equal to CD: Let Ka be made equal to CA. Now ſince (by the laſt Corollary) taking the Times equal before and after the Stroke, the Diſtances of the Bodies from the common Center of Gravity, will always be equal; at the ſame Point of Time that the common Center of Gravity is at K, the Body A will be at a; therefore after the Stroke its Motion from D towards a, and its Velocity will be as the right Line Da, which it runs thro' in that Time; but by reaſon that CE is equal to the right Line CD or KD, and CA equal to Ka, the Difference of the right Lines CE, CA, will be equal to the Difference of the right Lines KD, Ka, that is, EA will be equal to Da; but the right Line Da denotes the Velocity of the Body A after the Stroke, therefore its Velocity will alſo be expreſs'd by the right Line EA: Beſides, ſince the relative Velocity of

Lect. VI. of Bodies remains the same after the Stroke as before, and the right Line EA expresses the Velocity of the Body A, the Velocity of the Body B after the Stroke must needs be express'd by the right Line EB; that is, from E towards B. *Which was to be demonstrated.*

Corollary 1.

If the Body B is at rest, the Point D will coincide with the Point B, as in the three first Figures: and because B : is to A : : as AC : to CB; therefore by compounding of Proportion B and A taken together will be to A : : as B : to CB; whence doubling the Consequents B and A taken together: will be to 2 A : : as AB : to 2 CB, or EB; that is, as the Aggregate of the Bodies : to double the impingent Body : : so is the Velocity of the impingent Body : to the Velocity of the Body that was at rest before the Stroke.

Corollary 2.

Therefore if A and B are equal, A and B taken together will be equal to 2 A, whence EB the Velocity of the Body B after the Stroke, will be equal to the Velocity of A before the Stroke, and consequently the Point E co-inciding with the Point A, AE the Velocity of A after the Stroke will be equal to nothing; which may also be easily shewn thus ——Since the Bodies A and B are equal, these Quantities will be equal, $AC = CB = CD = CE$; therefore the Point E will coincide with the Point A, and consequently the Body A will be at rest after the Stroke, and the Body B will after the Stroke move with the Velocity EB, or AB. If therefore an elastick Body comes upon another equal to it which is at rest, the percutient Body will be at rest after the Stroke, and the Body that was at rest will go on with all the Velocity of the Percutient.

Corollary 3.

Plate 3. Fig. 4. If the Bodies A and B, still suppos'd equal, move the same way (*Fig.* 4.) after the Stroke, they will still go on the same way, interchanging their Velocities. For since CE is equal to CD, and AC to CB, $CE - AC$ (that is EA) will be equal to $CD - CB$ or BD; and therefore the Velocity of the Body A after the Stroke will be equal to the Velocity of the Body B before the Stroke: Besides, because EA is equal to BD, EB will be equal to AD, and therefore the Velocity of the Body B after the Stroke will be equal to the Velocity that the other Body A had before the Stroke.

Corol-

COROLLARY 4.

IF the Bodies A and B (still suppos'd equal) move towards each other in contrary Directions, (as in *Fig.* 8.) they will, after the Stroke, recede towards contrary Parts, changing their Velocities. For since A C is equal to C B, and C E to C D, A C — C E (that is A E) will be equal to C B — C D, or B D; therefore the Velocity of the Body A, after the Stroke, will be equal to the Velocity of the Body B before the Stroke: Besides, because E A is equal to B D, A D will also be equal to E D; but A D was the Velocity of the Body A before the Stroke, and E B is the Velocity of the Body B after the Stroke, which proves the Corollary. Plate 3. Fig 8.

36. FROM a Consideration of the foregoing Corollaries, it is easy to reduce the Matter to Practice; and shewing the manner of finding what the Velocities of elastick Bodies will be after their Congress, to reduce all the particular Cases to Numbers. But we will shew the Thing now by a few Experiments, referring the curious Reader to the Notes for a general Calculation exprefs'd algebraically *.

* Ann. II.

EXPERIMENT I. *Plate* 3. *Fig.* 12.

THE Ivory Ball A, weighing two Ounces, with the Velocity 16, comes upon the Ivory Ball B, which, after the Stroke, goes forward to *b*, with the Velocity 16, the percutient Body A remaining at rest in the Place of B after the Stroke.

THIS Phænomenon may be very easily explain'd, by considering the first Experiment of the Congress of soft Clay Balls shewn in the second *Figure* of *Plate* 2. For if the Body A made use of here had no Elasticity, it would (by striking its equal B) lose half its Velocity at the Contact; but the Magnitude of the Stroke being equal to what A loses, B being elastick must be bent in with the Force that A loses; and as Reaction is equal to Action, B will restore itself to its Figure with all the Force of the Stroke that bent it in, and therefore give the percutient Body eight Degrees of Velocity in the Direction B A, which being equal, and contrary to what A had left in the Direction B *b*, destroys the Motion of A, and brings it to rest. Now as A is elastick, in the Stroke it is bent equally with, and as well as, B; and by restoring itself to its former Figure, gives B eight Degrees of Velocity besides the eight which it had given it by the Stroke: so that B by that means has 16 Degrees of Velocity; that is, the same Velocity as the percutient A.

COROLLARY.

37. HENCE follows, that whatever Velocity a Body without Elasticity would gain or lose (that is, would acquire either forward or backward) in its Congress with another Body without Elasticity; the Body will acquire double that Velocity, if the Bodies are elastick: and therefore it is easy from the Congress of Bodies without Elasticity to know what will happen in the Congress of elastick Bodies.

EXPERIMENT 2. *Plate* 3. *Fig.* 13.

LET the same Bodies A and B go the same way, A with 16 Degrees of Velocity, and B with 8: after the Stroke, A will have 8, and B 16; that is, the Bodies will interchange their Velocities.

HAD A not been elastick, after the Stroke it would have gone along with B to 12, losing four Degrees of Velocity; but as it is elastick, it must lose eight, and there it goes but to eight at *a*. For the same Reason had B not been elastick, it must have gone to 12, gaining four Degrees of Velocity; but as it is elastick, it must gain four more, and consequently go to 16 at *b*.

EXPERIMENT 3. *Plate* 3. *Fig.* 14.

THE same Bodies A and B coming from different Parts meet one another full, A with 16, and B with 8 Degrees of Velocity: A returns to 8 at *a*, and B to 16 at *b*, here also interchanging their Velocities.

HAD the Bodies been void of Elasticity, both wou'd have gone towards B after the Stroke with the common Velocity 4; that is, A would have lost 12 Degrees of its Velocity towards B; but as it is elastick it must lose 24, or in receiving 12 more in the Direction B A, it loses its four Degrees towards B, and goes back eight more towards A. Likewise B, which, if it had not been elastick, would have gone back after the Stroke in the Direction A *b* four Degrees towards *b*, (losing 12 Degrees of its Velocity) will go to *b* with 16 Degrees of Velocity, losing 12 more Degrees of Velocity in the Direction B A, or which is the same thing, acquiring 12 more in the Direction A *b*.

EXPERIMENT 4. *Plate* 3. *Fig.* 15.

LASTLY, let the two Bodies A and B meet one another, each with 16 Degrees of Velocity, and after the Stroke they will fly back from one another with the very same Velocity.

HAD they not been elastick, they would both have stood still at S; but each of them having lost 16 Degrees of Velocity by the Stroke at S, must

muſt loſe 16 more by the unbending of the Surface of the other Body: but theſe Bodies, which had 16 Degrees of Velocity each, cannot loſe 32 Degrees, but by receiving 16 Degrees the contrary way, and going back again. Lect. VI.

Now ſome People, who have not read with ſufficient Attention what has been ſaid before, may imagine that the Rule does not hold true; *viz.* that in the direct Stroke of all Bodies, (elaſtick or not elaſtick) there is as much Motion before as after the Stroke; becauſe in this Caſe the Bodies, if not elaſtick, would have been at reſt after the Stroke, and now as they are elaſtick, A has 16 Degrees of Velocity, and B alſo 16. But it is to be obſerv'd, that we ſaid, *there will be after the Stroke the ſame Quantity of Motion towards the ſame Parts, as before the Stroke.* And this is evident here. For as in Bodies not elaſtick, the Stroke brings the Bodies to reſt; here in the elaſtick Bodies, the Motions given to them after the Stroke are equal and contrary; that is, poſitive and negative, which being added, deſtroy one another; for whether we conſider the Motion as directed from A to *b*, or from *b* to A, we ſhall always find + 16 — 16, or — 16 + 16 equal to nothing.

38. If a little elaſtick Body comes upon a greater elaſtick Body that is at reſt, the little Body will be reflected. This will alſo happen if the great Body meets the little one; or, going the ſame way with leſs Velocity, is overtaken by it; becauſe (*by Rules* 9, *and* 10) the Caſe will be the ſame as if the great Body was at reſt, and the little one came upon it with the relative Velocity of the Bodies.

Experiment 5. *Plate* 3. *Fig.* 16.

The elaſtick Body A, weighing two Ounces, comes upon the elaſtick Body B, which is at reſt, and weighs four Ounces. B goes on in the Direction of A with the Velocity 8, and A comes back in a contrary Direction with the Velocity 4.

Without Elaſticity B would have gone forward but four Degrees, gaining only that Velocity; and A would have gone along with it loſing eight Degrees of Velocity. But adding the Force ariſing from the Elaſticity, and B gains four Degrees more to come to *b*, whilſt A loſes eight of Velocity more to bring it back to *a*.

Experiment 6. *Plate* 3. *Fig.* 17.

The elaſtick Body A, weighing two Ounces, with the Velocity 15 comes upon the elaſtick Body C at reſt, whoſe Weight is eight Ounces, which for the ſame reaſon will go forward to 6, whilſt A returns to 9.

Experiment 7. *Plate* 3. *Fig.* 18.

The elaſtick Body A, weighing two Ounces, with the Velocity 18, comes upon the elaſtick Body D, which is at reſt, and whoſe Weight is 16 Ounces. B goes on forward with four Degrees of Velocity, and A returns back with 14. N. B. *The Velocities of the Bodies after the Stroke in theſe three laſt Experiments, if they had not been elaſtick, are always found by the Rule given in the Account of Experiment* 6, *and Experiment* 7, *of* Plate 2.

Scholium.

39. Here it is obſervable, that if you add the Momentum, or Quantity of Motion of the little Body A before the Stroke, to the Momentum which it receives in being driven back by the Stroke, (without any regard to, or comparing the Directions of thoſe Motions) the Sum of theſe *Momenta* will be equal to the Momentum with which the great Body goes forward. In the Experiment of *Fig.* 16. $A = 2 \times 12 + a$ ($= 2 \times 4$) gives 32, equal to 4×8, the Momentum of B. In *Fig.* 17. $2 \times 15 + 2 \times 9$ gives 48, equal to 6×8, the Momentum of C: and in *Fig.* 18. $2 \times 18 + 2 \times 14$, gives 64 equal to 16×4, the Momentum of D.

Corollary.

40. Hence in the Congreſs of two elaſtick Bodies, of which only the Weight of one is known, we may find the Weight of the other, by obſerving the Velocity of the Bodies before and after the Stroke. For example, if the Weight of the little Body be unknown, divide the Momentum of the great Body by the Sum of the Velocities of the little Body before and after the Stroke: as here in Experiment 5. *Fig.* 16. $\frac{32}{12 + 4} = 2$, the Weight of the Body A. In Experiment 6. *Fig.* 17. Suppoſe the Weight of C was unknown, divide the Sum of the Momenta of A before and after the Stroke, by the Velocity of C after the Stroke. That is, $15 \times 2 + 9 \times 2 = 48$, divided by 6, the Velocity of C, gives 8 for its Weight, *&c.*

41. Now ſince from 24, the Momentum given to A in the fifth Experiment, (*Fig.* 16.) you have a Momentum of 32 produc'd in B: and from 30, the Momentum of A in the ſixth Experiment, (*Fig.* 17.) you have a Momentum of 48 produc'd in C; and from 36, the Momentum of A in the ſeventh Experiment, (*Fig.* 18.) you have a Momentum

mentum of 64 produc'd in D; one would imagine that Motion may be increas'd by the Congreſs of Bodies, from a ſmall Momentum to a much greater, ſo as to apply it to Uſe in Mechanicks. This made a very learned and ingenious Gentleman imagine, that upon this Principle the perpetual Motion was not impoſſible; eſpecially when he conſider'd, that if a Series of elaſtick Bodies bigger than each other in a Geometrical Progreſſion, are ſuſpended from the ſame Height, ſo as to have their Centers in the ſame Line, by letting the ſmalleſt Body ſtrike the reſt with any Momentum, the Motion will be propagated thro' the whole Series of Bodies, ſo as to make the laſt (which is the biggeſt) go forward from the reſt with more Momentum than the firſt came on, in any Proportion. This will be made plainer by the three following Experiments. Lect. VI.

EXPERIMENT 8. *Plate* 3. *Fig.* 19.

LET the elaſtick Body A, of two Ounces, come with nine Degrees of Velocity upon the elaſtick Body B, of four Ounces, and B will go to *b* with ſix Degrees of Velocity; ſo that the Momentum 18 in A has produc'd the Momentum 24 in B.

EXPERIMENT 9. *Plate* 3. *Fig.* 20.

LET the elaſtick Body B, of four Ounces, be at reſt, as alſo the elaſtick Body C, of eight Ounces, with their Centers in the ſame horizontal Line. Now let the elaſtick Body A, of two Ounces, come full upon them with the Velocity 9, and C will fly off to *c* with the Velocity 4; ſo that the Momentum 18 in A has produc'd the Momentum 32 in C.

EXPERIMENT 10. *Plate* 3. *Fig.* 21.

LET the elaſtick Bodies B, C, and D, whoſe Weights are 4, 8, and 16 Ounces; that is, whoſe Weights are in a Geometrical Progreſſion, be ſuſpended with their Centers in the ſame horizontal Line touching one another. Then let the elaſtick Body A, of two Ounces, come upon B, and D will fly off to *d* with the Velocity $2\frac{2}{3}$; ſo that the Momentum 18 in A has produc'd 42 and $\frac{2}{3}$ in D.

BUT here lies the Fallacy *. We think we have gain'd ſo much Motion towards E, as the Exceſs of the Momentum of B, C, or D above that of A. Not conſidering that the Effect we have produc'd is caus'd by a Syſtem of Bodies, *viz.* of two Bodies, *Fig.* 19. of three Bodies, *Fig.* 20. and of four Bodies, *Fig.* 21. in which Caſes we muſt only reckon the Motion produc'd towards E, which cannot be done but by ſubſtracting the Motion towards contrary Parts; that is, ſubſtracting the Motion

* Plate 3. Fig. 19, 20, 21.

Lect. VI. in the Direction E A. In Experiment 8. *Fig.* 19. A returns from B to *a* with the Velocity 3, its Momentum being 6. Now as that is a negative Motion in reſpect of that of the Body B towards E, it muſt be ſubſtracted from 24, the Momentum of B; then we ſhall have only 12 left for the Momentum of B towards E after the Stroke, the very ſame as the Momentum of A before the Stroke. Likewiſe in Experiment 9. *Fig.* 20. which is a Syſtem of three Bodies, if we only reckon'd the Momentum of C going to *c* in the Direction C E, with four Degrees of Velocity, we ſhould gain the Momentum 20, over and above 8 that was given at firſt by A. But we muſt now not only ſubſtract 6, the Momentum of A going back from B to *a*, but alſo the Momentum of B going back to *b* in the Direction E A, with two Degrees of Velocity, that is 8, from 32 the Momentum of C after the Stroke: and then we ſhall have only 18 Degrees of Motion left towards E, the ſame that A had that way before the Stroke. For $32 - \overline{6 + 8} = 18$.

In the ſame manner, in Experiment 10. *Fig.* 21. where the Momentum of D after the Stroke is $42\frac{2}{3}$, inſtead of gaining $24\frac{2}{3}$, the Exceſs of that Momentum above 18 the Momentum of A, we gain juſt nothing. For as the Bodies A, B, and C, are all reflected towards A, we muſt ſubſtract all their Momenta (which now are negative Quantities, as their Directions are in the Line E A) from $42\frac{2}{3}$, the Momentum of D, and then we ſhall have juſt as much Momentum left in D, as the Momentum of A before the Stroke. The negative Momentum of A after the Stroke, which carries it back from B to *a* is 6; the negative Momentum of B reflected from C to *b* is 8; and the negative Momentum of C reflected from D to *c* is $10\frac{2}{3}$. Now the Sum of all theſe $(6 + 8 + 10\frac{2}{3})$ $24\frac{2}{3}$, ſubſtracted from $42\frac{2}{3}$, the Momentum of D towards E, leaves juſt 18, the Momentum of A towards E before the Stroke.

42. As we have not yet mention'd any Experiment of the percutient Body, or the Ball A (*Plate* 2d and 3d) being greater than B, we will here make one Experiment of that ſort, which may be applied to all Caſes of that kind.

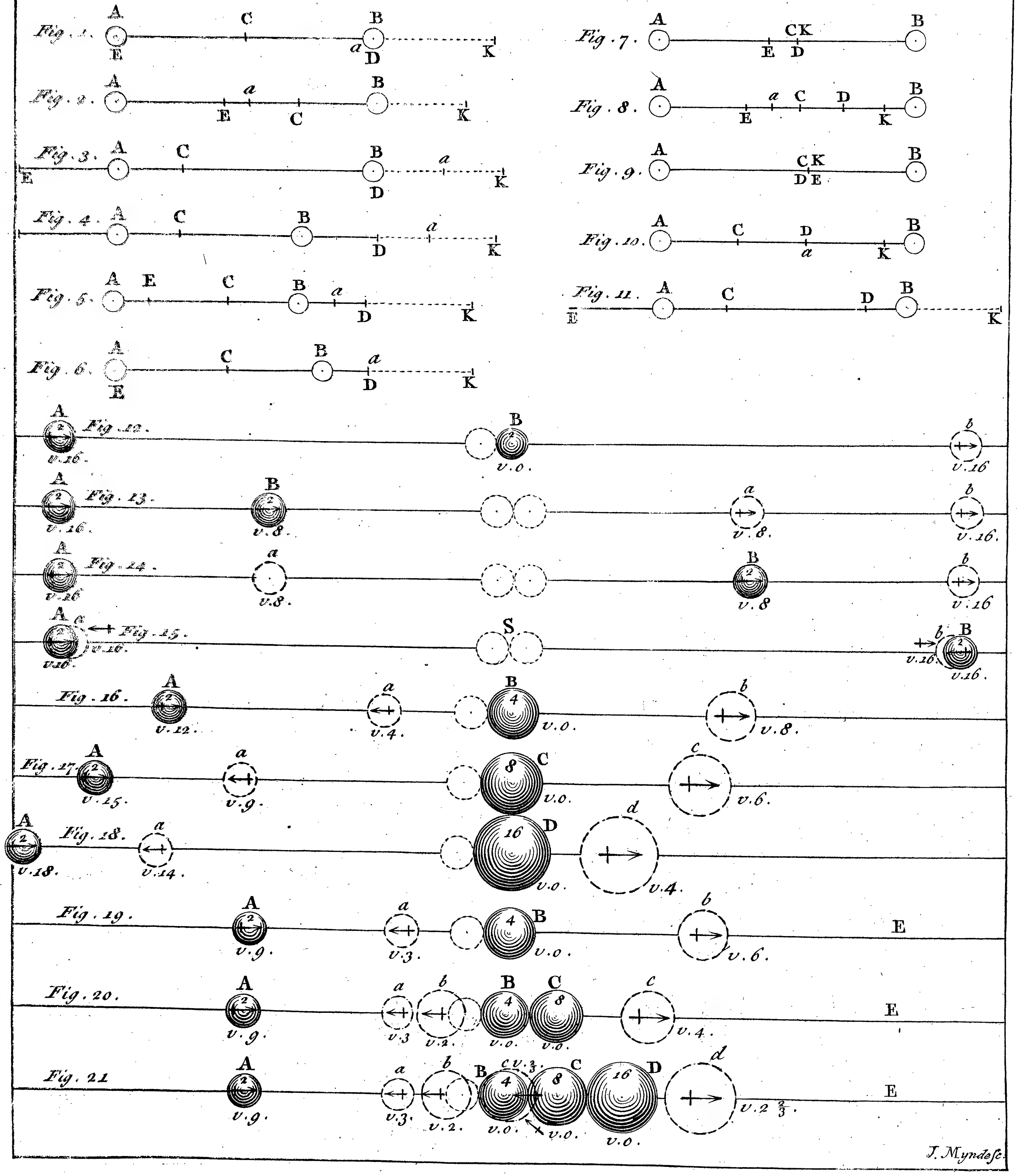
EXPERIMENT 11. *Plate* 4. *Fig.* 1.

Plate 4. Fig. 1. Now let the elaſtick Body A weigh four Ounces, and come with 12 Degrees of Velocity upon another elaſtick Body B, which is at reſt, and weighs but two Ounces; after the Stroke the Body A will go to 4, and B to 16, towards E. Had the Bodies been without Elaſticity, they would have gone together to 8, A loſing four Degrees of its Velocity, and B gaining eight. But as they are both elaſtick, A muſt loſe eight Degrees, and B

muſt

pa. 28.

Plate III.



muſt gain 16, which agrees with the Experiment, for the Reaſons given before. Lect. VI.

There is a pretty odd Phænomenon depending upon Elaſticity, which therefore I thought proper to take notice of here; which is, that if a Row of Shovel-Board Pieces (that is, metalline Cylinders of about half an Inch in Height, and two Inches Diameter) be laid upon a ſmooth Table, and you take a ſingle Piece, and drive it againſt the Row, by its Stroke upon the firſt Piece the laſt Piece will fly off; as for Example, let the Row of Pieces be B, C, D, E, F, G, H, I, *Plate* 4. *Fig*. 2. if A, a Piece of the ſame kind, be puſh'd in the Direction A *a* againſt the Row of Pieces, ſo as to ſtrike the firſt of them, the laſt Piece I will fly off to *i*, with the ſame Velocity that A came againſt B: and whether A comes on with a greater or a leſs Velocity, no other Piece but the laſt Piece I will fly off, and that exactly with the ſame Velocity that A ſtruck at the other End. But if you take two Pieces, as A and B, *Plate* 4. *Fig*. 3. and puſh them together in a Line againſt the Row C, D, E, F, G, H, I, the two Pieces H, I, will fly off from the other End of the Row with the very ſame Velocity that A and B made their Stroke, be the Stroke ſtronger or weaker, going to *h*, *i*. If three or more Pieces are made uſe of to make the Stroke, then will fly off at the End the very ſame Number that made the Stroke, &c. *N. B.* The ſame will happen with equal elaſtick Balls ſuſpended in a Row by Strings of the ſame Length. Plate 4. Fig. 2. Plate 4. Fig. 3.

Now if we conſider this well, it will only appear to be a Caſe of Experiment 1, *Plate* 3. *Fig*. 12. N° 36. as will more eaſily be conceiv'd by making the

Experiment 12. *Plate* 4. *Fig*. 4.

Let A be one of the fore-mention'd Pieces, at the diſtance of about ten Inches from B, and C be placed in the ſame Line at about four Inches from B: then if A be puſh'd againſt B with any Degree of Velocity, it will ſtand ſtill after the Stroke, and B will go on with all the Velocity that A had; but then B ſoon coming againſt C, will ſtand ſtill alſo after the Stroke, whilſt C goes on with all the Velocity it receiv'd from B, that is, all the Velocity that A had at firſt. Now to apply this to the laſt Experiment, (*Fig*. 2.) it is plain that A having been the percutient elaſtick Body, B, C, D, E, F, G, H, do ſucceſſively become percutient Bodies, and ſucceſſively ſtand ſtill after their Strokes; whilſt I, which has no other Body before it to ſtrike, goes on with all the Velocity of the firſt percutient A. Plate 4. Fig. 4.

If

Lect. VI. Plate 4. Fig. 3. If the Stroke be made with two or more Pieces (*Fig.* 3.) it will admit of the ſame Solution; only that here the Body B will have the ſame Effect by its Stroke on the Row before it, and ſtrike off the laſt Body I; but at the Inſtant of the Stroke as it is dented in, and its Circumference towards C a little flatted, it quits the Body A for a Moment; then immediately the Body gives its Stroke, and ſtrikes off the Body H which is now the laſt. In like manner if there had been three Pieces, there would have been three ſucceſſive Strokes on the Row, &c. This is made ſtill plainer if you join the two or three Pieces (that you make your Stroke with) with Solder or even Glew, ſo that they may not part from each other in the Stroke; for then no ſuch Effect will happen as that the ſame Number of Pieces ſhall fly off at the End of the Row as gave the Blow at the Beginning of it.

In making all the abovementioned Experiments with elaſtick Bodies, it will be found that after the Stroke ſomething will be wanting of the Velocities mentioned; which is on account of the Elaſticity not being perfect in the Bodies which we make uſe of: But yet all the Concluſions will be certain, if we allow for the Imperfection of the Elaſticity; becauſe when we know how much the Bodies want of perfect Elaſticity, we may find exactly what will be the Effect of their Congreſs, as is ſhewn in the 11th Annotation to this Lecture. *

* Ann. 11.

To know exactly how much a Body wants of perfect Elaſticity, that is, how much the reſtitutive Force falls ſhort of the compreſſive, we need only repeat the Experiment of *Plate* 3. *Fig.* 12. and obſerve how much the Body ſtruck wants of the Velocity of the Percutient. But this will appear plainer in *Plate* 4. *Fig.* 5. where A and B repreſent two equal elaſtick Bodies, of which A is the Percutient, and B is at reſt till the Stroke. Here we may obſerve, that B does not go quite to *b* after the Stroke, that is, has not the full Velocity of A, (as we have all along ſuppoſed, when we conſidered the Bodies as perfectly elaſtick) but goes only to 15, if the Bodies are Glaſs, to 14 if the Bodies are of hard Steel, and to about 14 and a half when they are of Ivory. So that the Elaſticity of Glaſs is to perfect Elaſticity, as 15 to 16; that of Steel as 14 to 16; and that of Ivory as $14\frac{1}{2}$ to 16. *Thus may be found the Elaſticity of any Subſtance, by making Balls of it to ſtrike againſt each other.*

Plate 4 Fig. 5.

To conclude this Lecture, we will in a few Words diſpatch all that relates to oblique Percuſſion.

That the Obliquity of a Stroke diminiſhes its Force, is evident to Senſe; and how much it diminiſhes has been ſhewn both in the firſt Volume †, and in the Beginning of this Lecture; we ſhall therefore here

† Lect. 3. Annot. 7. &ſeq.

here only mention what we are previously to take notice of concerning oblique Strokes, without giving a particular Demonstration. Let A B, (in the second Figure of the first Plate of this Volume) represent an Obstacle against which a Body runs obliquely in the Line G c : the Magnitude of the Blow is as much less in this oblique Stroke, than it would have been if the Line G c, in which the Body moves had been perpendicular, as the right Sine G E of the Angle E c G is less than the Radius c G; and if both the Obstacle and the percutient Body be elastick, the Body will be reflected in such manner, that the Angle of Reflection will be equal to the Angle of Incidence; that is, G c D will be equal to H c D. Lect. VI. Plate 1. Fig. 2.

The oblique Congress of Bodies that have no Elasticity will be easily explain'd in the following manner, (Plate 4. Fig. 6.) Plate 4. Fig. 6.

The Bodies A and B, supposed equal, are to move obliquely towards one another in the Directions A C and B C. Draw the Lines A C and B C, and divide into two equal parts the Angle ACB, which they make by the Line LC produced on towards l. Perpendicular to L C at L draw A B : compleat the Parallelograms L D and L G, by drawing thro' C, D G parallel to A B and A D and B G parallel to L C. Produce A D to E and B G to F, and draw E F thro' l, parallel to D G, which will compleat the two other Parallelograms D l, C F. Let A C, the Motion of the Body A, be resolved into two Forces, one acting along A D, and the other along A L. It is plain that the Force A D does nothing towards driving the Body towards B, or towards the Line L l, the Force A L only being employ'd to bring the Body to the Line L l; for the same Reason, of the two Forces B L and B G, which act upon the Body B, only the Force B L brings the Body B towards A: but as the Forces A D and B G carry the Bodies towards l, or toward the Line E F, they will meet one another obliquely at C, the Magnitude of the Stroke being equal to A L or B L, which is the Sine of the Angle of the Obliquity, instead of A C or B C the Radius. This will be just as if the Bodies had come from D and G, and had met at C; which if they had done with equal Velocities, they would have stood still, those equal Velocities destroying each other. But now since the Forces A D and B G were not destroy'd, we must transfer them to C l, equal to A D and to B G; there is then Force left to carry A towards l, with the Velocity C l, and B also towards l with the Velocity C l. But equal Bodies that have no Elasticity and go the same way, will go on after the Stroke with half the Sum of their Velocities *; and therefore our two Bodies will go together to l, because C l is equal to half of 2 C l.

* Rule 6. Pag. 11.

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In the ſame manner may be found the Motion of the Bodies, if their Velocities or Forces had been unequal. Suppoſe A being placed at H had come to C with the Velocity H C, whilſt B came to C with the greater Velocity B C. Having as before reſolved the Motion of each Body into two Forces, A (ſuppoſed to ſet out from H) would with the Force H K (or its equal IC) meet B at C coming againſt it with the Force B L (or its equal GC.) Now this being the ſame as if they came againſt each other from I and G, with the Velocities I C and G C; after the Stroke they will go on together with half the Difference of the Velocities; ſo that their common Velocity will be C N, which has been taken equal to D O, the half of D I, the Difference of C D and C I, reſpectively equal to B L and H K their Velocities.

How to find out the true Motion of the Bodies going together after the Stroke, let us conſider how the Forces H I and B G do now act upon them. We muſt transfer H I, the Force acting on A (or H) to C M, and the Force B G acting on B to C *l*: C *l* + C M therefore will be the Sum of the Velocity of the Bodies, and C *m* (taking *l m*, *m* M, and N C all equal) will be half that Sum, the Velocities that the Bodies would, according to the Rule * given, have after the Stroke. But ſince by the former Action of the Forces H K and B L, the Velocity C N was left to the Bodies moving together; we may now look upon the join'd Bodies as acted upon by two Forces, as C N and C *m*; to which Lines drawing *m a* and N *a* parallel, you will have C A for the Diagonal of the Parallelogram N *m*, in which Diagonal the Bodies going together, will move.

* Rule 6. Pag. 11.

Remembring what has been ſaid in this Lecture, it will alſo be eaſy to ſhew the Effect of the Congreſs of elaſtick Bodies. Fig. 7.

A B *b a* is a Parallelogram in which are drawn the Diagonals A *b* and and B *a*; and the Angles which the Diagonals make, are divided into two equal Parts by the Lines L *l* and D E; ſo that the Lines AB, BE, and C *l* are equal, as alſo the Lines A L, B L, DC, E C. Now let A and B be two equal elaſtick Bodies meeting at C in the Directions, and with the Velocities A C, B C. I ſay, that after the Stroke they will go to *a* and *b* reſpectively, the Angles of Incidence A C D, and B C E, being equal to the Angles of Reflection D C *a*, E C *b*, each to each. Since the Forces A C and B C, muſt be reſolved each into the two A D, A L, and B E, B L; firſt, the ſame thing will happen as if the Bodies had met at C, with the equal and contrary Forces D C and C E; from whence (by the Rules of the Congreſs of elaſtick Bodies) A muſt have return'd with its own Velocity to D, and the Body B to E: Then taking the Bodies ſingly, we ſhall find that beſides the Force which

which the Body A has to bring it back to D by the Restitution of B, it has also the whole Force A D, which is not destroy'd, but transferred to C l its equal and Parallel; whence the said Body A acted upon by the two Forces C D and C l must move in C a, the Diagonal of the Parallelogram D l. After the same manner the unimploy'd Force of B (*viz.* B E) being transferred to C l, B will move in C b the Diagonal of the Parallelogram E l, by the Action of the joint Forces C E, C l. Lect. VI. Plate 4. Fig. 7.

But if the equal elastick Bodies come together obliquely with different Forces, for Example, A * has the Velocity A C, and B the Velocity B C, the Angles of Incidence and Reflection in each Body will not be the same before and after the Stroke; for the Body which has most Motion before the Stroke, will have its Angle of Reflection greater, and its Momentum less than before the Stroke; and that which had least Motion before the Stroke, will have its Angle of Reflection less than that of Incidence, but its Momentum greater than before the Stroke. A C D is the Angle of Incidence of A before the Stroke, and the greater Angle D C a its Angle of Reflection, and C a less than A C its Momentum; whilst BCE (= A C D) is the Angle of Reflection of B before the Stroke, and the less Angle E C b is the Angle of Reflection of B after the Stroke, and C b greater than B C its Momentum. * Plate 4. Fig. 8.

Demonstration.

The Body A consider'd as acted upon by the two Forces A D and A L, strikes B at C only by the Force A L equal to D C, as if it came in the Direction and with the Velocity D C. The Body B considered as acted upon by the two Forces B H and B F, strikes A at C only by the Force B H equal to F C, as if it came in the Direction and with the Velocity F C. Now by the Restitution of the Bodies (according to the Rules and Experiments already explain'd) they must interchange Velocities with each other in contrary Directions, so that A will go back to I with the Velocity C I equal to CF, and B will go back to E with the Velocity C E equal to C D. Now let us take in the two Forces unimploy'd before the Stroke, *viz.* A D and B F. We will first consider them in the Body A, transferring A D to C l. Complete the Parallelogram I l by drawing I a and $l a$. Now A is acted upon by the two Forces C I and C l, therefore it will go in the Diagonal C a of the Parallelogram I l, where the Angle of Reflection D C a is bigger than the Angle D C G, and consequently than its equal A C D the Angle of Incidence: And the Diagonal C a expressing the Momentum of A after

the

Lect. VI. the Stroke, is shorter than CG (because of CI less than CD) equal to CA expressing the Momentum of A before the Stroke. In like manner it may be shewn that B after the Stroke will be reflected in the Line C*b*, so as to make the Angle of Reflection EC*b* less than the Angle of Incidence BCF; and to have its Momentum C*b* after the Stroke greater than the Momentum BC, which it had before the Stroke.

The End of the SIXTH LECTURE.

ANNO-

ANNOTATIONS upon the Sixth Lecture.

1. [1. *The Doctrine of the Congress of Bodies*, &c.—*is so extensive*, &c.]

ALL sorts of Machines which are mov'd by Wind or Water, are govern'd by Rules deduc'd from the Congress of Bodies, elastick or not elastick, acting upon one another directly or obliquely, with conspiring, or contrary Motions. Those who understand mechanical Principles, and the Theory of Engines, will easily find how to apply the Principles to all Shipping, from a Man of War to a small Boat; to Wind-Mills, whatever kind of Work they are to perform, as also to Water-Mills, whether over-shot or under-shot; to all Works where Percussion is used, as *forging* and *battering* by Engines, and to driving of Piles into the Earth, whether under Water or above; and many more Machines which do not occur to me at present: Nay, there may be many new Machines invented depending on the Laws of the Congress of Bodies. But as it may be expected that I should be more particular, I will here shew how the Water acts upon the under-shot Wheel of a Water-Mill by the Rules of the Congress of Bodies. Annotat. Lect. VI.

LET us suppose W A the Height of the Water in an under-shot Mill-Dam, the Penstock being open'd at A, so as to have an Aperture of a square Foot, whose Center is 13 Foot below the Surface: the Force of the Water coming out at the said Opening E F (whose Center is A) to strike the Ladle-Board B of the under-shot Wheel V D B C, is to be consider'd as the Weight of a Pillar, or Body of Water, whose Base is a square Foot, and Height 13 Foot, which will be equal to about 806 Pounds Averdupoids, striking against the Ladle-Board B with the Velocity with which the Water issues out at A. Now let us suppose the Work to be done by the Wheel, the Friction of the whole Machine, and Resistance of the Air, to be equal to the Weight *w*, equal to 806 ℔. hanging at the Circumference of the Wheel: What else will be the Operation of the Water upon the Wheel, but the Congress of two Bodies without Elasticity, as mention'd in the Congress of the Balls A and B, in N° (32) of this Lecture, *Plate* 2. *Fig*. 6. for here the Wheel is as a Body of 806 ℔. suspended at B, and the Water is as a Body of the same Weight moving from A to B with a certain Degree of Velocity. After the Shock, both will go on with half the Velocity of the Percutient. Had the Resistance of the Wheel, on account of the Geer in the Mill, and Work to be done, been greater, then the common Velocity of the Water and the Wheel after the Percussion had been less. Now, tho' there be by the Stroke of the Water a new Percussion every Instant, the Comparison still holds good; because, as the Work of the Mill is doing, there is also a new Resistance every Instant. Plate 4. Fig. 9.

 Had

Annotat. Lect. VI. Had the Wheel not been loaded at all, the Water would have been some little time in putting the Parts of the Wheel in motion; but when once it had receiv'd its Motion, it would have kept it, and gone very near as fast as the Water flying round before it, being check'd only by the Resistance of the Air, and a little Friction of the Gudgeons. In this way the Phænomenon would have been as when a percutient Body strikes, and carries with it another much less than itself. I shall in my Hydrostaticks consider this Subject fully, and shew wherein consists the Perfection of an under-shot Mill. What I have said here is sufficient to shew the Truth of what I have laid down, especially when we consider that the Wind, or Air, is a Fluid like Water acting upon its Solids by its Matter and its Velocity.

[5.—*Mention them in the Notes; not as true, but probable Causes.*] The mutual Attraction of small Particles of Matter, and mutual Repulsion of others, have been already shewn *. Attraction and Repulsion seem to be settled by the great Creator as first Principles in Nature; that is, as the first of second Causes; so that we are not solicitous about their Causes, and think it enough to deduce other things from them. If Elasticity was admitted as *a first Cause*, (as it is by some) it is thought we should admit of too many principal Causes in Nature, which is contrary to the Rules of good Philosophy *. Philosophers therefore have endeavour'd to deduce Elasticity from Attraction, or from Repulsion, or from both. It is observ'd, that the same Particles that repel each other strongly, will attract other Particles very strongly; as appears by many Chymical Dissolutions, especially by the alternate Dissolution and Precipitation of Metals in acid Menstruums. The reverend and learned Dr. *Hales* has prov'd this many Ways, in his *Vegetable Staticks* and *Hæmastticks*. The Elasticity of Air seems to consist wholly in the repulsive Power of its Particles, which do not touch one another while the Air is in its elastick State; and if those Particles be brought nearer and nearer together, the Effect of their repulsive Force will increase, the Air's Elasticity being always proportionable to its Density by Compression, which Property will be preserv'd, tho' compress'd Air be kept a Year or two; notwithstanding Mr. *Haukshee*, in his *Physico-mechanical Experiments*, says, that Air will lose Part of its Spring by being very much compress'd. But the Air with which he try'd it must have been fill'd with moist Vapours, and it is well known that the Steam of Liquors will lose its Elasticity, especially where its Heat decays. I have kept several Wind-Guns strongly charg'd for half a Year together, in which the Air had lost none of its Elasticity: others have found the Air as strong after a Year; and I have been told by a Person of Credit, that a Wind-Gun having been laid by and forgotten for seven Years, when it was found, discharg'd its Air as many Times, and with as much Force as it used to do; nay, and I have read that a Wind-Gun has remain'd fully charg'd 16 Years. Now, tho' Air compress'd by any external Force does always increase in Elasticity, as it diminishes in Bulk; yet it may by Fermentation diminish its Bulk very much, without gaining any more Elasticity: For if another Fluid, whose Parts repel one another, but attract the Parts of Air, be mix'd with Air, the Repulsion

* L. 1.

* L. 1.

of any two Particles of Air will be diminiſh'd, in proportion as a Particle of the other Fluid inſinuating itſelf between them, attracts them towards itſelf on either ſide. The ſame thing will happen to the other Fluid in reſpect of the Particles of Air, which, mixing with its Particles, do in the ſame manner deſtroy their Repulſion. Thus, if we allow an Attraction ſtrong enough between the Parts of two elaſtick Fluids, it is poſſible, that by Fermentation a Solid may be made out of two elaſtick Fluids, which would have ſtill continued fluid without ſuch a Mixture. We are taught by Chemiſtry to mix Fluids together, which immediately coaleſce into a Solid. When Brimſtone Matches are burning, the Effluvia of the Sulphur repel each other to great Diſtances, as may be known by the ſulphureous Smell upon ſuch an Occaſion: Now tho' theſe Particles repel each other, they attract the Air very ſtrongly, as appears by the following Experiment.

Take a tall Glaſs Receiver, clos'd at top with a Cock, holding about four Quarts of Air, and having put its open End over a Bundle of Brimſtone Matches on fire, ſtanding up in the middle of a large Diſh with Water in it, (to keep the Air from coming in at the bottom of the ſaid Receiver) you will obſerve, that not only as ſoon as the Matches are burnt out, but a good while before, the Air, inſtead of being expanded by the Flame of the Brimſtone, will retire into leſs Compaſs, the Water beginning to riſe from the Diſh up into the Receiver, and continuing ſo to do till ſome time after the Matches are burnt out; ſo that there will be in the Receiver only three Quarts of Air, inſtead of four, (more or leſs, in proportion to the Quantity of Brimſtone burnt:) And this plainly happens by ſome of the Effluvia, or little Parts of the Sulphur attracting ſome of the Particles of the Air, ſo as to make an unelaſtick Compound that precipitates into the Water. If the Elaſticity of the Air is quite loſt when the Repulſion of its Particles is taken off, or ſufficiently counter-acted, it muſt follow, that its Elaſticity depends upon Repulſion: And that this is often the Caſe, appears by a great number of Dr. *Hales*'s Experiments, of which I'll mention but a few. The Doctor took half a Cubic Inch of Deer's Horn, and having put it into his Gun-Barrel Retort, he diſtill'd out of it 117 Cubic Inches of Air into a large Glaſs Bottle, the Weight of which Air, together with the Aſhes of the Horn left, weigh'd as much as the whole Quantity of the Horn did at firſt. Now the Air had been confin'd in that Horn, together with many ſulphureous Particles, in ſuch manner, that the mutual Attraction of the Sulphur and the Air had alternately deſtroy'd each other's repulſive Force, and brought thoſe Subſtances into a little Compaſs; but the Fire in the Diſtillation ſeparated them from each other, ſo as to reſtore them in a great meaſure to their uſual Elaſticity. This appear'd by bringing a Candle near the Mouth of the Bottle that held this reviv'd Air; for every time the Candle was brought near, the Air took fire, and flaſh'd out of the Bottle with a ſulphureous Smell. The Air may be conſolidated in many hard Bodies, ſo as to be there quite void of Elaſticity, and there do the Office of a Cement, till by the Action of Fire, or ſome particular Fermentations, it is again reſtor'd to its perfectly elaſtick State. This is the Meaning of the Doctor's Words, when he ſays, that ſome Bodies *abſorb*, and others *generate* Air; and the ſame Bodies

Annotat. Lect. VI. dies do sometimes absorb, and at other times generate Air. He found more or less Air in almost every solid Substance that he try'd; but what was most remarkable, he found that the *Calculus humanus* (or Stone taken out of a Man's Bladder) was made up of about two third Parts of Air.

Plate 4. Fig. 10. SOME have endeavour'd to solve Elasticity by Attraction only; as for example, if the String A B (*Plate* 4. *Fig.* 10.) be consider'd as made up of Particles lying over one another in the manner represented at A D B; it is plain that if the Point D be forcibly brought to *c*, the Parts will be pull'd from each other, and when the Force that stretch'd the String ceases to act, the Attraction of Cohesion (which was hinder'd before) will take place, and bring back the String to its former Length and Situation, after several Vibrations. Now, tho' this seems to agree pretty well with the Phænomena of a String in Motion, it will by no means solve the Elasticity of a Spring fasten'd at one End, and bent either way at the other, like a Knife or Sword-Blade, as in *Fig* 11 *. For if such a Spring be bent from A to *a*, the Particles on the Side C, which now becomes convex, will be farther asunder at F, while the Particles at D, carried to the concave Part E, will come closer together: So that the Attraction, instead of making the Spring restore itself, will keep it in the Situation in which it is, as it happens in Bodies that have no Elasticity, where perhaps only Attraction obtains. Thus a Plate of Lead, a Plate of Copper, and a Plate of soft Iron stands bent.

* Plate 4. Fig. 11.

BUT the most probable way of solving the Elasticity of Springs, is, to consider both a repulsive and an attractive Property in the Particles, after the manner of the black Sand, which is attracted by the Load-stone, and has been shewn by the learned and ingenious Professor *Petrus Van Muschenbroek* to be nothing else but a great number of little Load-stones.

* Plate 4. Fig. 12. LET us suppose a Row of round Particles * touching one another only in the Point *c* in a Line from A to B. It is plain, from what we have said in our first Volume concerning the Attraction of Cohesion †, that upon the least Shake or Alteration out of the Position of a strait Line, these Particles will run together, and form a Sphere, in which the Globules will have more Points of Contact. But if these Particles have Poles like Magnets, in the opposite Places mark'd *n*, *s*, so that all the Poles *n*, *n*, *n*, *&c.* repel one another, and all the Poles *s*, *s*, *s*, *&c.* do likewise repel one another, the Line A B will continue strait; for if by any Force the said Line B A be put into another Position, as into the Curve *b a*, then the Poles *n*, *n*, *&c.* being brought nearer together, (while the Poles *s*, *s*, *&c.* are farther asunder) will repel one another more strongly, and thereby hinder the Globules from running together towards the concave Part, and the Spring left to itself (all this while supposing one End, as *b*, B, or β fix'd) will restore itself, throwing its End *a* back to A, and so on to α by the first Law *: then being in the Position α β, the Poles *s*, *s*, *&c.* are brought nearer together, whose Repulsion thus increas'd throws back α to A, and so on forward, the Line of Particles performing several Vibrations round B.

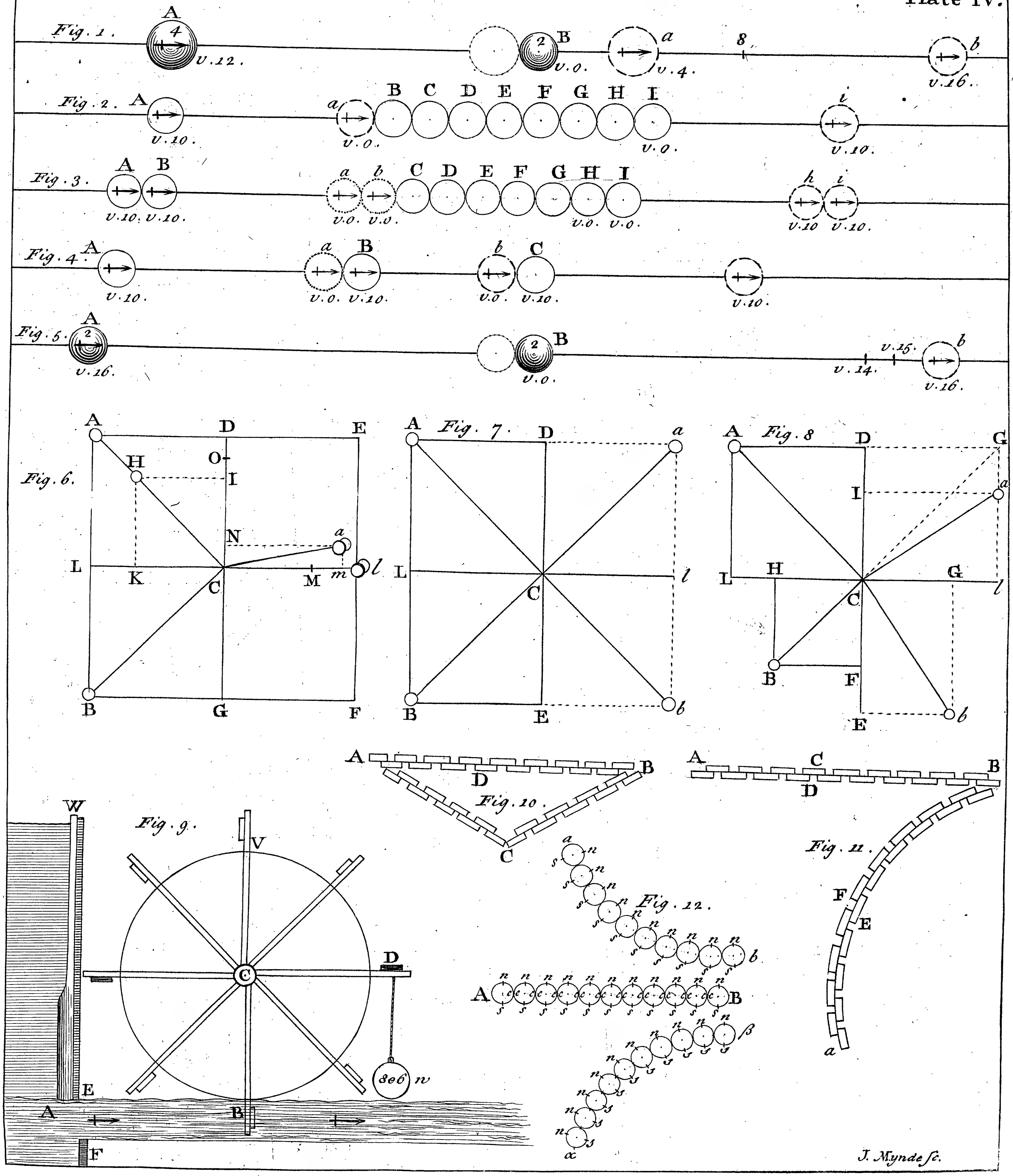
† L. 1. Ann. 15.

* L. 5. N° 2.

MAY not a Spring of Steel, or other Springs, consist of several Series of such Particles, whose Polarity and Attraction acting at the same time, will

shew

Plate IV.



J. Mynde sc.

ſhew why ſuch Bodies, when they have been bent, vibrate and reſtore themſelves? Annotat. Lect. VI.

If we take a Plate of Steel, and make it ſo hot till it looks white, and then immediately quench it, we thereby fix the Metal in a State very near Fluidity, ſo that the Particles which the Fire had almoſt brought to Roundneſs, have but a very ſmall Contact, as appears by the Fragility of the Steel thus harden'd, which breaks like Glaſs, and has a ſhort Grain. Steel thus harden'd is highly elaſtick; for what Workmen call *hard* is the moſt *elaſtick*: as appears by the Congreſs of high harden'd Steel-Balls, which return, in their Rebound, the neareſt to the Place we let them fall from, and, next to Glaſs, have the quickeſt Elaſticity of any thing we know.

That we may not be thought to have given an imperfect Account of the Elaſticity of a Steel Spring, becauſe ſuch an one as we have deſcrib'd wants Toughneſs, and will immediately fly when bent to any Degree: we muſt beg leave to conſider farther the Properties of the round Particles, or little Spheres of Steel in which we have ſuppos'd a Polarity.

Let us ſuppoſe A and B (*Plate* 5. *Fig*. 1.) to be two little Spheres, or component Particles of Steel, in which at firſt we will ſuppoſe no Polarity, but only an Attraction of Coheſion. Then, whether the Particles have their Contact at *c*, *d*, *e*, *n*, or at *δ*, *ε*, *s*, their Coheſion will be the ſame, and the leaſt Force imaginable will change their Contact from one of thoſe Points to another; becauſe in the rolling of theſe little Spheres they do not come into more or leſs Contact in one Situation than another. But if we ſuppoſe the Point *n* in each Spherule to be a Pole with a Force to repel all the other Points *n* in any other Spherule; and likewiſe *s*, another Pole repelling the other Points *s*; the Spherules will cohere beſt, and be at reſt in that Poſition where the Points *c c* are in Contact, and *n* and *s* at equal Diſtances on either ſide. For if the Spherules be turn'd a little, ſo as to bring the Points *d*, *d*, into Contact, as in *Fig*. 2 *, the Poles *n*, *n*, being brought nearer, act againſt each other with more Force than the Points *s*, *s*, which are now farther off, and conſequently drive back the Spherules to the Contact at *c*, *c*, beyond which continuing their Motion, they will go to *δ δ*, (*Fig*. 3) and ſo backwards and forward, till at laſt they reſt at *c*, *c*, which we may call *the Point of Æquilibrium for Reſt* in a Spring. Now there are beſides this two other *Points of Æquilibrium*, beyond which the Spring may break, which are the Points *e*, *e*, towards *n*, and *ε*, *ε* towards *s*, (ſee *Fig*. 4 †.) that is, when the Spherules have their Poles *n*, *n* brought very near together, the mutual Repulſion increaſes ſo, that the Attraction at the Contact is not able to hold them, and then they muſt fly aſunder, the Spring breaking. We ſuppoſe the Points *e*, *e*, to be the Points of Contact beyond which this muſt happen; but that if the Contact be ever ſo little ſhort of it, as between *e* and *d*, the Spherules will return to their Contact at *c*, after ſome Vibrations beyond it, as has been already ſaid. This is the reaſon why I call *e*, (in one of the Spherules) and its correſpondent Point *ε*, on the other Side *c*, the Points of Æquilibrium; for if the Spring be bent toward *a*, (*Plate* 4. *Fig*. 12.) ſo that the Spherules like A and B, (*Plate* 5. *Fig*. 1.) touch beyond *e*, the Spring will break; likewiſe if the

Plate 5. Fig. 1.

* Plate 5. Fig. 2.

Fig. 3.

† Fig. 4.

Plate 4. Fig. 12.

Annotat. Lect. VI. the Spring be bent the other way, till the Spherules touch beyond ε, then it will break the other way. Now when the Spherules touch at e, e, or at ε, ε, the Spring is as likely to return to its firſt Poſition as to break; for which Reaſon I have call'd the Points e and ε, Points of *Æquilibrium*, as alſo having known by Experience, that a Spring left bent to a certain Degree has, after ſome time, broke of it ſelf.

From all this it appears, that ſpherical Particles will never make a tough Spring; therefore the Figures of the Particles muſt be altered, in order to render it uſeful; and this is what is done in bringing down the Temper of the hard Steel, and *letting down a Spring*, as it is called. What Change ought to be made in the Particles, we ſhall firſt ſhew; and then conſider how far that is done by thoſe who make Springs.

Fig. 1. If the Parts ſuppoſed globular, as in *Fig.* 1. are now flatten'd at c where
Fig 5. the Contact is, ſo as to put on the Shape $n\,d\,\delta\,s$ (as in *Fig.* 5.) the Contact will be much increas'd, and reach from d to δ, ſo that in bending the Spring there will ſtill remain a great Contact in the Particles, and the Points of Æquilibrium for breaking (*viz.* e, e above, and ε, ε below) will be removed nearer to the Poles n, or s, than when the Particles are round; the conſequence of which will be, that the Spring muſt be bent much farther to be in danger of breaking than in the former Suppoſition, as may be ſeen in *Fig.*
Fig 6. 6. where two Particles being open'd about the Point d as a Center, the attracting Points c, c, and δ, δ have ſtill ſome Force to help to bring back the Particles to their whole Contact; becauſe in this Shape of the Particles the attracting Points c, c, δ, δ are removed but in Proportion to their Diſtance from the angular Point d; whereas if the Particles had been ſpherical, and the Line $d\,\delta$ an Arc of a Circle, the attracting Points c, c, and δ, δ wou'd have removed from one another farther than in Proportion to twice the Square of the Diſtance from d (as in *Fig.* 2.) and ſo have afforded very little help for bringing back the Particles to their Contact. A Row of Particles in the Spring thus conſider'd, is to be ſeen in the natural State at B A, *Fig.* 7. and bent at $b\,a$ in the ſame Figure. Here it is to be obſerved, that if in this Figure of the Particles you wou'd bend the Spring to bring the Particles to touch at their Point of *breaking Æquilibrium*, you muſt open them ſo much on the contrary ſide, that the Spring will be bent far beyond any Uſes intended to be made of it, as appears by *Fig.* 8. where two Particles are brought to touch at the equilibrating Point e, and by *Fig.* 9. where many Particles being put into that Condition, the Spring is brought round quite into a Circle.

Now the common Practice in making Springs, is the moſt likely to produce this Effect required in the Particles; for the hard Spring whoſe Particles were round, or nearly ſo, is heated a-new, and whilſt it is cooling gently, the mutual Attraction increaſes the Contact, ſo that the Particles grow flatter in thoſe Places where before they had but a ſmall Contact; and leſt this Contact ſhould become too great, the Spring's ſoftening is ſtopped by quenching it in Water, or Oil, or Greaſe. Another way of making Springs, is to begin and ſhape them in cold unelaſtick Steel, and then having heated them to a

ſmall

ſmall Degree, for example to a blood-red Heat, immediately to cool them in ſome proper Liquor. This alſo ſettles the Particles in their oblong Figure, thro' which they muſt paſs before they become round, or nearly ſo, in a white Heat. That Particles of Steel are fixed in the Figures which they have at the Inſtant of dipping, will not appear ſtrange when we conſider that dipping red-hot Steel in cold Liquors in a particular Poſition, makes it magnetical. If it be aſk'd, how we account for making Springs only with hammering, it is eaſily anſwered, that we can make Iron and Steel magnetical only with hammering; and if we can give and deſtroy Poles in the whole Piece, there is no improbability to think we can give Poles to little Parts; or rather bring into a particular Situation the Poles which they have: for if the Poles that we have conſider'd be placed quite irregularly, there will be no Elaſticity at all. Agreeable to this, Springs may be made of other Metals than Iron or Steel, tho' not ſo perfect, by hammering; for it will be ſufficient for the little Particles to have Poles that attract and repel one another, driven by the hammering into a regular Order.

Annotat. Lect. VI.

NB. *This applied to the Vibration of a String, will better ſolve its ſeveral Caſes than Attraction alone*; and the Elaſticity of Glaſs is juſt the ſame as that of a very brittle Steel Spring.

2. [11. —*Why Glaſs is ſooner broken within than at the Surface, and—that broken Part becomes viſible and ſhining.*] In Number 10. of this Lecture (*Plate* 1. *Fig.* 3.) we have conſider'd the Particles of Glaſs lying in equidiſtant *Strata*, as ſo many Strings repreſented by the Lines A B, which being ſtruck at D, are inflected towards C, as the pointed Lines repreſent. Now we muſt obſerve, that the longer Strings are, the ſlower are their Vibrations, and conſequently the weaker; ſo that if there be any Force applied to hinder a bent String from returning to its ſtreight Poſition, tho' it be inſufficient to effect it in a ſhort String, it may in one that is longer: and the ſame Reaſoning may be applied to longer or ſhorter *Strata* in the Glaſs. For Example, in the Ball A B D C, if by the Stroke given at D, which cauſes all the *Strata* A B to be bent into the Curves repreſented by the prick'd Lines, one of the longeſt of them as A B above C being bent into the Line A C B, be attracted more ſtrongly by the *Stratum* immediately below it, namely by A B under C, it will remain in that Place, (*viz.* at A B C) whilſt the other *Strata* return to their former Situation A B, A B, *&c.* ſo that there will be an Hollow from A C B to that *Stratum* A B, which is the ſecond above C. This making a great Opening between two Strata in the Body of the Glaſs, is the broken Part that we ſee. But how we come to ſee it, or how the Glaſs in that Place loſes its Tranſparency, cannot be explain'd without the Knowledge of ſome Properties of Light firſt diſcovered by Sir *Iſaac Newton.* We read in his *Opticks* that Rays of Light, in reſpect of tranſparent Bodies, have *Fits of eaſy Tranſmiſſion*, and *Fits of eaſy Reflection.* We ſhall not ſo far anticipate upon *Opticks* here, as to ſhew what puts the Rays of Light into thoſe *Fits*, and that Rays differently *refrangible* have a different Number of theſe Fits in the ſame Space.

Plate 1. Fig. 3.

Annotat. Lect. VI. It is only necessary for our purpose to shew what is meant by the Expression, and to apply the thing to the present Case.

Tho' a Ray of Light has some hundreds of these Fits in going the space of an Inch (*See Sir* Isaac Newton'*s Opticks*,) we will only now suppose five or six. Let A B G H (*Plate* 5. *Fig.* 10.) be a Body of Glass, in which we suppose the Strata to be A B, C D, E F, G H, and L ρ, R S, T I to be incident Rays of Light in which the Letters *r* and *t* mark the Fits of easy Reflection, and the Fits of easy Transmission, the last being also distinguish'd by little Strokes across, while the other are shewn by large Points. The Ray L ρ (whose Fits *r*, *t*, *r*, *t* we take no notice of, whilst it is above the Body of Glass) at the Surface, or first *Stratum* of the Glass, is in a Fit of easy Reflection, and therefore will be reflected by the first *Stratum* A B, shewing by its reflected Ray ρ *l* the Point of the Surface at ρ, or rather any Objects that might be in the Line L ρ, to an Eye at *l*. But if we consider the Motion of the Ray R S, which happens to be in a Fit of easy Transmission at the Surface of the Glass, or first *Stratum* A B, it will pass thro' that *Stratum*; then its next Fit being a Fit of easy Reflection, becomes ineffectual, because where it is, there is no *Stratum* of the Glass to reflect it: The next Fit happens at the second *Stratum* C B; and as it is a Fit of easy Transmission, the Ray goes thro' it, and the next Fit of easy Reflection becomes ineffectual, because it happens between the second and third *Stratum*: So the Ray goes on, and with its next Fit of easy Transmission passes thro' E F the third *Stratum*. The next Fit of easy Reflection falling between the *Strata* is ineffectual, and therefore the following Fit of easy Transmission carries the Ray thro' the last *Stratum* G H, and so out of the Glass. But if this last *Stratum* had by any means been displaced and brought higher, so that it had come to that Part of the Ray which was in a Fit of easy Reflection, it would have reflected the Ray, which in that case would not have gone thro' the Glass, but have come out again on the same side it went in at. Another Ray more oblique, as T I, might go thro' all the Body of the Glass in the manner above described, and yet by being in a Fit of easy Reflection at the under Surface be reflected up again thro' the first Surface. Thus, if you hold a Glass Prism (as P P I, *Fig.* 11.) with one of its Surfaces downwards and horizontal as P P, oblique Rays of Light as R N will be in their Fits of easy Reflection at the last *Stratum*, or under Surface P P at N, and be reflected up again towards ρ; but if the Angle R I N had been less, the Rays of Light would have pass'd thro' the Glass without any Reflection.

Plate 5. Fig. 10.

Plate 5. Fig. 11.

* Fig. 12.

Now, if a Ball of Glass * A F B E D, which is entire within and without, be exposed to such a Ray of Light as goes into it, as R*r*, that Ray will pass quite thro' it, its Fits of easy Reflection happening always between the *Strata*, where there is no Glass to render them effectual. But if, by a Blow given to the Ball at F, the *Strata* are bent in, so that the *Stratum* A B is left behind between the next *Stratum* D E, and the Place where it was before; then the Ray of Light being in a Fit of easy Reflection just at that *Stratum*, that *Stratum* will render that Fit effectual, and reflect the Ray back to G, where an Eye

being

being placed, will see the broken Place within the Glass at C, *which was to be explained.* Annotat. Lect. VI.

3. [—— *There are two Sorts of Vibrations in elastick Bodies,* &c.] When a String vibrates very slow, the Tremor of the Parts is not strong enough to give a Sound. It has been observed, that unless it vibrates $12\frac{1}{2}$ Times in a Second, it produces no Sound; and when it does vibrate $12\frac{1}{2}$ Times in a Second, it gives the gravest Tone or lowest Note: And when it gives the sharpest Tone or highest Note, it vibrates 6400 Times in a Second. As we intend to be more particular upon Sound in its proper Place, we say no more about it here.

4. [16.——COROLLARY I. *From hence it follows, that if one Body strikes against another, which is either at rest, or moves more slowly according to the same Direction, the Sum of the Motions in the two Bodies towards the same Parts, will be the same after the Stroke as before.*] Let the Body A move in the Direction C D from C towards D, and let it strike against another Body B, that is either at rest, or moves slower in the same Direction: I say, the Sum of the Motions in both Bodies towards the same Parts, namely from C towards D, before and after the Stroke, will remain the same. Let C D express the Motion of the Body A, and if the Body B moves, let the right Line E F represent its Motion towards the same Parts, and therefore the Sum of the Motions may be express'd by the Sum of the right Lines C D, E F. Now, since Action and Reaction are always equal and contrary, the equal Forces impress'd towards the contrary Parts, will produce in both the Bodies equal Changes of Motion towards the contrary Parts: If therefore the Motion impress'd on B by the Stroke of the Body A, shall be represented by F G, the contrary and equal Force acting on the Body A, will take as much from its Motion made towards the same Parts; so that by putting D K equal to FG, C K will be as the Motion of the Body A, and E G as the Motion of the Body B, after the Stroke or Concourse; and therefore the Sum of the Motions will be as the Sum of the right Lines C K, E G. But since FG is equal to K D, if to both there be added E F and C K, then E G and CK will be equal to C D, E F: Whence the Sum of the Motions towards the same Parts will remain the same, both before and after the Stroke. If F G is equal to C D, the Point K will co-incide with C, and C K will become equal to nothing; whence after the Stroke the Body A will be at rest. But if FG is greater than C D, the Point K will fall beyond C, and the Motion of A will become negative, or towards the contrary Parts, *viz.* from C towards K; and the Sum of the Motions towards the Parts G, will be as E G lessened by C K: for the Sum of two Quantities, whereof one is positive, the other negative, is their Difference. But because F C=K D, let E F—C K be added to them both, and it will be E F+F G—C K: that is, E G—C K=K D+E F—C K, that is, E F+C D: Whence the Sum of the Motions towards the same Parts, which is here the Difference of the Motions towards contrary Parts, before and after the Stroke, remains the same. *Q. E. D.*

Plate 5. Fig. 13. Fig. 14. Fig. 15.

Cor.

Annotat. Lect. VI. *Cor.* After the same manner, if more Bodies moving towards the same Parts strike against one another, the Sum of their Motions will not be alter'd.

5. [16. —*if two Bodies in contrary Directions meet one another full, the Sum of the Motions towards the same Parts*, &c. *will continue the same before and after the Meeting*, &c.] Let the Body A move from C towards D, whose Motion let be expres'd by C D; but let B be moved towards the contrary Part, namely from E to F, with a Motion as E F: Let D H be put equal to E F; and C H, which is the Difference of the Motions towards the contrary Parts, will be as the Sum of the Motions towards G: I say, the Sum C H will be as the Sum of the Motions towards the same Part G after the Stroke. For let the Motion of the Body B after the Stroke be towards the Part G, and let it be represented by the right Line E G; the Force therefore of Impulse impres'd on B towards the Part G, will be equivalent to the Sum of the Motions E F, E G, and will be represented by the right Line F G: For by that Force is destroy'd the Motion as E F, towards the Part F, and a new one, as E G, is impres'd towards the contrary Part G. But since the Force of Impulse acts equally on both Bodies towards the contrary Parts, if D K is made equal to F G, it will represent the Force exercised on the Body A, towards the Part contrary to its Motion; so that if the Motion as D K is subtracted from the Motion as C D, there will remain C K as the true Motion of the Body A towards the Part G. Now since D K is equal to F G, and D H equal to F E, it will be D K, lessened by D H, that is K H equal to F G, lessened by F E, that is E G: And therefore since K H is equal to E G, K H will be as the Motion of the Body B after the Stroke; but C K is as the Motion of the Body A, so that C K, K H, that is, C H will be the Sum of the Motions in both Bodies towards the Part G. *Q. E. D.*

Fig. 16.

If F G is equal to C D, the Point K will fall on C, and then the Motion of A will become equal to nothing; that is, the Body A after the Stroke will be at rest, and C H will be equal to E G. But if F G is greater than C D, the Point K will fall beyond C towards the other Part, and the Motion of the Body A will be from C towards K; but (by reason F G is equal to D K, and F E equal to D H) K H is equal to E G: And therefore, if from both there be taken C K, it will be C H equal to the right Line E G, lessened by C K. But C H was as the Sum of the Motions towards the Part G before the Stroke, and it is E G lessened by C K, as the Sum of the Motions towards the same Part, namely, as the Difference of the Motions towards the contrary Parts after the Stroke. Wherefore the Sum of the Motions towards the same Part will remain the same before and after the Stroke.

Fig. 17. Fig. 18.

6. [17. *The common Center of Gravity of two or more Bodies*, &c. *is either at rest, or moves uniformly in a right Line.*

Fig. 19. The first Case. Let the Bodies A and B tend towards contrary Parts, whose common Center of Gravity let be C. By reason of the equal Quantity of Motion in both Bodies, the Velocity of the Body A will be to the Velocity of the Body B, as the Body B to the Body A; that is, (from the Nature of the

Plate V.

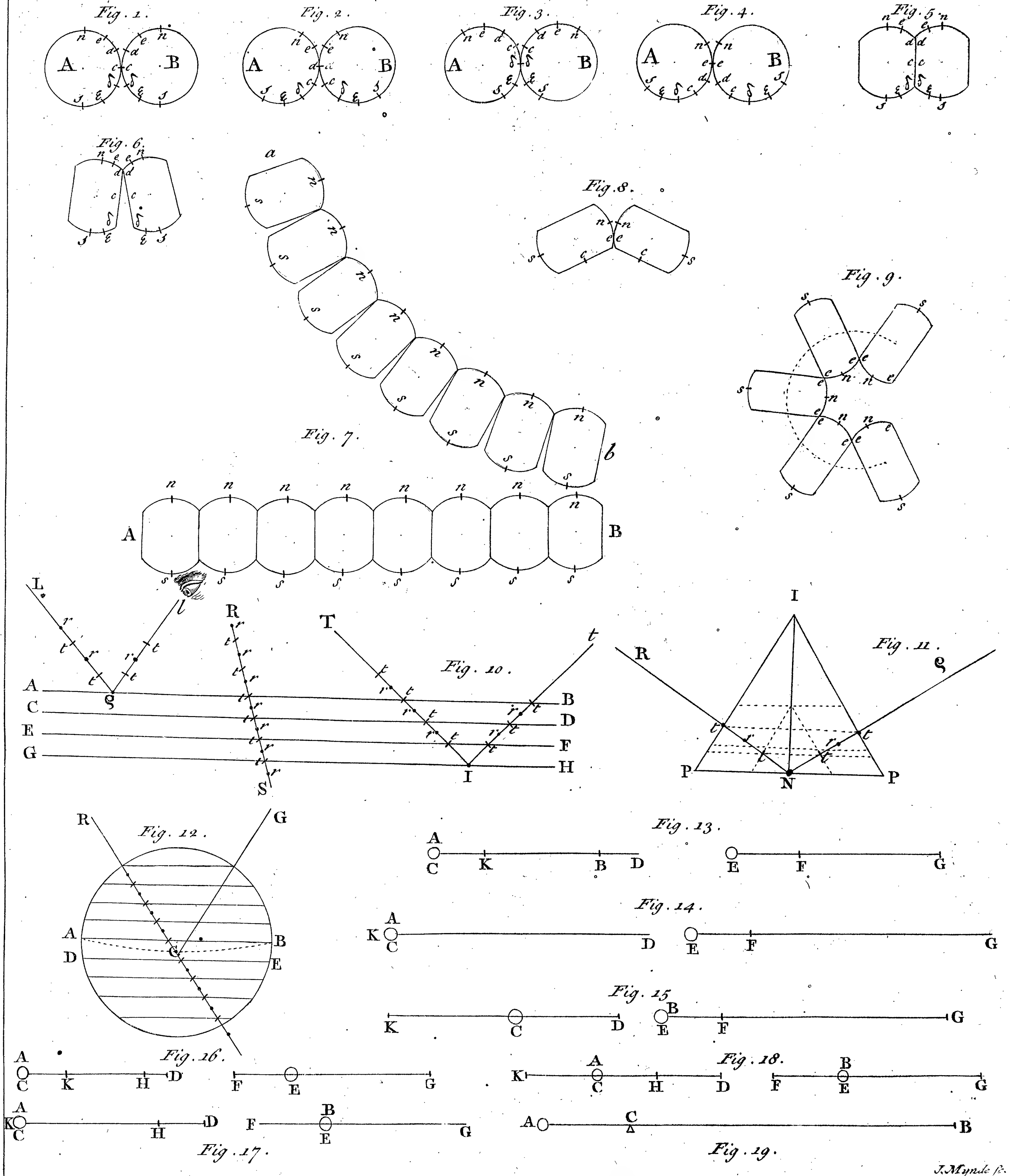


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
J. Mynde sc.

the Center of Gravity) as A C to B C: whence the Spaces paſſed over in the ſame time being proportionable to the Velocities, whilſt the moving Body A runs through the Length A C, the Length B C will be run through by the moving Body B; ſo that the Bodies will meet in the Point C, and in that Point will be their Center of Gravity at the time of their Concourſe; but it was in the ſame Point before the Concourſe, ſo that it remained in the ſame place. Annotat. Lect. VI.

IT may be ſhewn, after the ſame manner, that if the Bodies receded from the Point C with equal Motions, their Center of Gravity would have been at reſt.

THE ſecond Caſe. If Bodies are carried in the ſame right Line towards the ſame Part, or with unequal Motions towards contrary Parts, their common Center of Gravity will be always found in the ſame right Line. For ſince the Bodies do uniformly and directly recede from one another, or approach one another, their Diſtance from one another will be uniformly increaſed or diminiſhed; and therefore the Bodies will uniformly recede from, or approach to, any Point, dividing the aforeſaid Diſtance in a given Ratio. The Diſtance therefore of the Bodies from their common Center of Gravity, will be uniformly increaſed or diminiſhed; which cannot be in the aforeſaid Caſes, unleſs that Center is either at reſt, (as in the firſt Caſe) or moves uniformly, as in the preſent Caſe.

THE third Caſe. Let the Bodies A and B move in the right Lines A C, B D; and let the Spaces A C, C E, paſſed over by the Body A in equal Times, be equal; and the Spaces B D, D F, paſſed over by the Body B in the ſame Times, be alſo equal. Let the right Lines A C, B D, meet in G; and let it be as A C to B D, ſo is A G to G H, and join A H; to which, through C and E, let C I, E K, be drawn parallel: it will be A C to H I, as A G to G H; that is, as A C to B D; wherefore H I is = B D, and therefore H B = I D. In like manner, C E is to I K, as A G to G H, or A C to B D; that is, as C E to D F; wherefore I K is = D F, whence K F = I D = H B. Let L be the common Center of Gravity of the Bodies, when they are placed in the Points A and B; draw L M parallel to B D; the right Lines A B, A H, will be cut ſimilarly: join G M, and let it be produced; this will cut the Parallels to A H in the Points N and O; *viz.* in the ſame Ratio as A H or A B is cut. Draw through N and O, parallel to B D, the right Lines N P, O Q; theſe will cut C D, E F, in the ſame Ratio as C I, E K, are cut; that is, in the ſame Ratio as A B is cut in L: but L is the common Center of Gravity of the Bodies when they are found in A and B; wherefore P will be their Center, when they are in the Points C and D, and Q, when in E and F. Beſides, M L is to H B as A M to A H, or as C N to C I, or as N P to I D: but H B and I D are equal; wherefore M L and N P will be equal: in like manner, N P and O Q will be equal. Since therefore the right Lines M L, N P, O Q, are equal and parallel, the right Line drawn through L, and parallel to M O, will paſs through the Points P and Q; and therefore the Center of Gravity will be always placed in the right Line L Q. Beſides, (by reaſon of the Parallels) A C is to C E as M N to N O; that is, as L P to P Q; wherefore (by reaſon A C is = C E) it will be L P = P Q. Therefore the common Plate 6. Fig. 1.

Annotat. Lect. VI. common Center of Gravity of Bodies is always in the same right Line, and passes over equal Spaces in equal Times. *Q. E. D.*

THE fourth Case. If the Bodies do not move in any one, but in different Planes, their Ways, and the Way of their common Center of Gravity must be reduced to the same Plane, by letting fall from every Point of the Ways Perpendiculars upon any Plane; and (after the same manner as in the preceding Case) it will be demonstrated, that the Way of the Center of Gravity thus reduced, will be a right Line: and since this is in any Plane assumed at pleasure, it is necessary that this Way or Path of the Center of Gravity of the Bodies, is a right Line. *Q. E. D.*

IN like manner, the common Center of these two Bodies, and any third one, is either at rest, or moves uniformly in a right Line, by reason the Distance of the common Center of Gravity of the two Bodies, and the Center of the third, is divided by it in a given Ratio. And after the same manner the common Center of these three Bodies, and a fourth, either is at rest, or moves in a right Line, by reason the Distance betwixt the common Center of the three, and the Center of the fourth Body, is divided by it always in the same Ratio; and so of any other number of Bodies. *Q. E. D.*

7. [20. *If two Bodies, whether equal or unequal, are carried towards the same Parts, with Velocities any how equal or unequal, the Sum of the Motions of the two Bodies is equal to the Motion that would arise, if each of them was mov'd with the same Velocity as their common Center of Gravity moves with.*]

Plate 6. Fig. 2.

LET the two Bodies be A and B, whose common Center of Gravity let be C, and let both the Bodies be carried towards D; I say, the Sum of the Motions in both Bodies will be equal to the Motion that would be produced, if both Bodies were carried towards D with the Celerity of their Center of Gravity C. For let the Body A in any given Time describe the Length A a, the Body B the Length B b, and in the mean while let the Way passed over by the Center of Gravity C be C G; and (by what we have said) the Lengths A a, B b, C G, described in the same time, will represent the Celerities of the Body A, the Body B, and the common Center of Gravity C respectively; but since the Quantity of Motion in any Body is as a Rectangle contain'd under the Quantity of Matter and the Celerity, so the Motion in the Body A will be as $A \times Aa$; and in the Body B as $B \times Bb$; and the Sum of the Motions will be as the Sums of these Rectangles, *viz.* as $A \times Aa + B \times Bb$. But (by the Def. of the Center of Gravity of Bodies) B C is to A C as A to B; and as A to B, so also (by the same Definition) is b G to a G: wherefore B C will be to A C, as b G to a G; whence [by 19 *El.* 5.] B C is to A C, that is, A to B, as $BC - bG$ to $AC - aG$; that is, as $CG - Bb$ to $Aa - CG$. So that (by 16 *El.* 6.) $A \times Aa - A \times CG$ will be equal to $B \times CG - B \times Bb$; and therefore $A \times Aa + B \times Bb$ will be equal to $A \times CG + B \times CG$: but the two Rectangles $A \times Aa$, and $B \times Bb$, are (as has been said) as the Sums of the Motions in both the Bodies: and the two Rectangles under A and C G, and under B and C G, will be as the Sums of the Motions that would arise, if both the Bodies were carried with the Celerity C G of the Center of Gravity; whence the Sum of the Motions in both Bodies

is

is equal to the Motion that would be produced, if both Bodies were carried with the Celerity of their common Center of Gravity. *Q. E. D.* Annotat. Lect. VI.

If there are three Bodies A, B, D, carried towards the same Part, let E be the common Center of Gravity of these three Bodies; the Sum of the Motions in the three Bodies will be equal to the Motion arising from the same Bodies, carried with the Velocity of the Point E. For let C be the common Center of Gravity of any two Bodies A and B, the Motion in these two Bodies (by what has been demonstrated before) will be equal to the Motion that would arise, if the Bodies coalesced in one were carried with the Velocity of the Point C; but also the Sum of the Motions (*viz.* the Motion of the Bodies so coalescing, and the Motion of the third Body D) will be equal to the Motion which would happen, if the Body coalescing out of the two was moved together with the third Body D, with the Celerity of the Point E; whence the Theorem holds also in this Case. Plate 6. Fig. 3.

The Demonstration is the same, if the Bodies do not move in the same right Line, but in Parallels, or also in Lines any how inclined. But in this Case it must be observed, that the Celerity of the Bodies, wherewith they are carried towards the same Part with the Center of Gravity, is not to be reckon'd by the Way which they really pass over, but only by the Way wherein they move according to the Direction of the Center of Gravity. For example, if two Bodies A and B are carried in the right Lines A *a*, B *b*, and C G is the Line described by the common Center of Gravity, whilst the Bodies pass over the Lengths A *a*, B *b*, and from the Points A, *a*, B, *b*, let fall the Perpendiculars A F, *a g*, B H, *b* K upon the right Line, C G. Now the Spaces which the Bodies pass over according to the Direction of the Point C, are not A *a*, B *b*, which are the absolute Spaces described by them; but the Space according to which the Body A is moved towards the Part D, and must be computed in the right Line F D, by the Length F *g*; for it moves so much, and no more, according to the Direction of the Point C. In like manner, the Space according to which the Body B is moved towards the Part D, is H K; and by that Space its Progress in the right Line H D is to be reckoned: so that the Celerities of the Bodies wherewith they are carried towards the same Part, are as the right Lines F *g*, H K; besides, A is to B as B C to A C, or (by reason of the equi-angular Triangles A C F, B C H) as H C to F C: whence the Demonstration will proceed as in the first Case. Plate 6. Fig. 4.

Theor.

8. [21. *If two Bodies are carried towards contrary Parts, the difference of the Motions towards contrary Parts, or, (which is the same) the Sum of the Motions towards the same Parts will be equal,* &c.]

Let the Bodies be A and B, whose Center of Gravity let be the Point C, and let the Body A move from A towards D, and the Body B towards the contrary Part from B towards E; let the Spaces described by the Bodies A, B, and Center C in the same time, be A *a*, B *b*, C G: these (by *Theor.* 6.) will represent the Velocities of the Body A, the Body B, and Center of Gravity C respectively; whence the Motion of the Body A is as A × A *a*, and the Motion Plate 6. Fig. 5.

Annotat. Lect. VI. tion of the Body B as $B \times Bb$; so that the Difference of the Motions will be $A \times Aa - B \times Bb$. Moreover, from the Nature of the Center of Gravity, BC is to AC as A to B; and as A to B, so will be bG to aG: wherefore it will be as BC to AC, so bG to aG. So that (by 19 *El.* 5.) BC will be to AC, that is, A to B, as $BC - bG$ to $AC - aG$; that is, A will be to B as $Bb + CB$ to $Aa - CG$; wherefore (by 16 *El.* 6.) the Rectangle under A and $Aa - CG$ will be equal to the Rectangle under B and $Bb + CG$; that is, $A \times Aa - A \times CG = B \times Bb + B \times CG$: whence it will be $A \times Aa - B \times Bb = A \times CG + B \times CG$; but $A \times Aa - B \times Bb$ is (as was said before) the Difference of the Motions towards the contrary Parts, or the Sum of the Motions towards the same, and $A \times CG + B \times CG$ is the Motion emerging, if both the Bodies should be carried with the Velocity of their common Center of Gravity; whence the Proposition is manifest.

Cor. 1.

If the Difference of the Motions towards the contrary Parts is equal to nothing; that is, if in both the Bodies the Quantities of Motion are equal, the common Center of Gravity in this Case will be at rest.

Cor. 2.

If there are several Bodies, either all carried towards the same Parts, or some towards the contrary Parts; the Sum of the Motions of all towards the same Parts will be the same, as if all were carried towards the same Part with the Velocity of the common Center of Gravity of them all.

Cor. 3.

The Motion therefore of many Bodies is to be reckoned from the Motion of the Center of Gravity, and their System will proceed forwards, or go backwards, ascend or descend as much, as their common Center of Gravity proceeds forwards, or goes backwards, ascends or descends.

9. [25.—*A general Solution of this Problem is given by a Calculation in the Notes.*] Let the Velocity of the Body A be call'd C, and the Velocity of the Body B be c; and if the Bodies are mov'd according to the same Direction, the Sum of the Motions in both towards the same Parts will be $AC + Bc$: but if they are mov'd towards contrary Parts, the Sum of their Motions towards the same Parts will be $AC - Bc$; but in all Bodies, the Sum of their Motions towards the same Parts is the same before and after the Impulse: wherefore the Motion of the Bodies after the Impulse will be either $AC + Bc$ or $AC - Bc$, according as the Bodies did tend towards the same, or contrary Parts. There is therefore given the Momentum of the Bodies carried with the same Velocity, whence their Velocity will likewise be known; namely, dividing the Momentum by the Bodies themselves, and the Quotient will give their Velocities, *viz.* $\frac{AC + Bc}{A + B}$ or $\frac{AC - Bc}{A + B}$; and if B is at rest, that is, if c be put equal to nothing, the Velocity of the Bodies will be $\frac{AC}{A + B}$.

10. [31.

10. [31.—*Pendulous Bodies*, &c. *their Shock will hardly agree with the Mass multiplied into the Square of the Velocity, and the known Laws of the Congress*, &c.] The Question to be decided here, is, whether the *old* or the *new* Opinion concerning the Measure of the Force of Bodies in motion is most agreeable to the Phænomena of the Congress of Bodies.

NOT to give the Reader the Trouble of going back to the first Volume, I beg leave to repeat here, that the old Opinion is, *that the Mass multiplied into the Velocity* is the Measure of the Force of a Body in motion: and the new Opinion is, *that the Mass must be multiplied into the Square of the Velocity*, to give the Measure of that Force.

I HAVE for many Years consider'd this Question, and the more I examin'd other People's Experiments and Demonstrations, as well as my own, made in favour of the old Opinion, the more I became confirm'd in my Belief of it: and yet, as I was always resolv'd to be impartial in the Case, I likewise examin'd the Experiments and Demonstrations in favour of the new Opinion, and found most of them to be true, as far as I could judge of them; but being certain of the Truth of the old Opinion, I imagin'd that there must be some Fallacy or Paralogism in the Experiments and what was given as Demonstration by the adverse Party, which I had overlook'd: especially when I really found some few of their Experiments to be inconclusive, and some of the Demonstrations not fair. I suppose on the other hand, that some very impartial Gentlemen on the other side of the Question, fully convinc'd by the Experiments and real Demonstrations for their Opinion, who could not but acquiesce in most of our Experiments and Demonstrations, did still retain their Opinion for the same Reason, and also that they found some of our Experiments inconclusive. But then it seem'd to me very strange, that there should be mathematical Demonstrations, and very plain Experiments, for and against the same thing, which made me almost quit the further Consideration of the Subject; but finding that in several mechanical Enquiries I must reason against what I knew to be true, by embracing the new or old Opinion; at last I found both Opinions to be true, and that several of the same Phænomena might be solv'd by Calculations drawn from either Opinion: the whole Dispute being only about Words. For the Word *Force*, whose Measure we have consider'd differently, is not taken in the same Sense, by our Adversaries and ourselves: and as every body is at liberty to define the thing about which they treat, provided they stick to that Definition in all their Reasonings; so whilst we mean different things by the same Word, we may both be in the right; and whilst either Party imagines that the others take the Word in the same Sense that they do, they may think them to be in the wrong. Tho' this Dispute has lasted many Years, (about 59 Years) yet it has been of use in Philosophy and Mechanicks, having given occasion to many Considerations, and the making of many Experiments unthought of before. Now to set this matter quite right, I shall shew what we mean by *Force*, and what those Gentlemen, whom we have call'd our Adversaries, mean by it: and then it will appear, that most of the Experiments and Reasonings on both sides will stand good; and are con-

Annotat. Lect. VI. clusive for the Measure of *Force* in the different Senses given to that Word: therefore, that we are not Adversaries in reality, tho' so call'd hitherto.

We (that is, the *English* and *French* Philosophers) mean by the Word *Force* the same thing as we do by *Momentum*, *Motion*, or *Quantity of Motion*, or *instantaneous Pressure*, the which, as we measure (in comparing Bodies in motion one with another) by the Mass multiplied into the Velocity; so it may be known by its Effect; that is, the Product of the Mass into the Velocity is expressive of what we call Momentum, or Force, whose Measure it is. And to be still plainer, when we consider Bodies going thro' a certain Space, we always consider the Time in which that Space is run thro', which we call the Velocity.

Our suppos'd Adversaries (that is, the *Dutch*, *Italian*, and *German* Philosophers) mean by the Word *Force*, or *Force inherent in a Body in Motion*, *that which it is able to produce*; or in other Words, *the Force* is always measur'd by the whole Effect produc'd by the Body in motion, until its whole Force be entirely communicated or destroy'd, without any regard to the Time employ'd in producing this total Effect; because they look upon this total Effect as the perfect and adequate Measure of what they mean by *Force*: agreeable to this receiv'd Axiom—That Effects are always proportional to their Causes.

To confirm what I have said concerning the Meaning which is given to the Word *Force* by our Adversaries, (I still use that Term *Adversary* only for distinction sake) I beg leave to quote some of Mr. Professor *s'Gravesande*'s Expressions upon that Subject, in the *Journal Historique de la Republique des Lettres*, for *November* and *December*, 1733. under the Title, *Nouvelles Experiences sur la Force des Corps en mouvement*, *par* G. J. s'Gravesande;—towards the End. "Il me semble que ceci (parlant de quelques Experiences) leve la "plus grande des Difficultés qu'on ait opposées jusqu'a present aux Experiences "alléguées pour prouver que la Force est proportionelle au Quarré de la Vitesse par la Masse———Je n'ajoute qu'un mot pour eviter toute Dispute inutile———le Mot de Force est equivoque; *mais dans tout ce que j'ai écrit "sur la Force des Corps en Mouvement, j'ai entendu par ce Mot, la Capacité "que ce Corps avoit d'agir sur les autres Corps en perdant son Mouvement.*"

In *English* thus——Methinks this (speaking of some Experiments) takes off the greatest of the Difficulties hitherto thrown in by way of opposition to the Experiments alledged to prove the Force to be proportional to the Square of the Velocity multiplied into the Mass——I add but one Word, to avoid all useless Dispute——*the Word* Force *is equivocal*; *but in all that I have written upon the Force of Bodies in motion, I have understood by that Word the Power or Capacity that the Body has to act upon other Bodies in losing its Motion.*

And a little lower he says, "qu'on donne au Mot de Force un autre sens; "qu'on dise que cet autre sens est plus naturel; je ne m'y oppose pas: tout ce "que j'ai voulu soutenir, c'est que ce que j'ai nommé Force doit-être mesuré par "le produit de la Masse & du Quarré de la Vitesse: pour soutenir qu'en envisageant la Force sous une autre façon on peut admetre un autre mesure, il "faut expliquer toutes les Experiences qu'on a fait sur la Force & le Chock,

"ce

" ce que nous faisons de notre côté; & que j'ose assurer que cela n'a pas encore " été fait par ceux qui ont embrasé le Sentiment opposé." Annotat. Lect. VI.

In *English* thus——*Let People give the Word* Force *another Signification; and let them urge, that that other Signification is more natural; I make no Opposition to it: all that I have been willing to maintain, is, that what I have named* Force *ought to be measur'd by the Product of the Mass into the Square of the Velocity. To alledge, that considering* Force *another way one may admit another Measure, one should explain all the Experiments that have been made upon the Force and Congress of Bodies, which we do on our Part; and which I dare say has not yet been done by those who have embrac'd the contrary Opinion.*

And a little before he said, " la Difficulté que nous venons d'indiquer, & " a laquelle les Defenseurs du Sentiment que la Force est proportionelle au " produit de la Masse par la Vitesse, sont obligés de recourir souvent est fondée sur ceci——que pour avoir l'effêt d'un Effort, il faut retrancher de " l'effêt que cet Effort fait d'un côté, l'effêt que ce même Effort fait du " côté opposé: au lieu que nous disons, que l'effêt total est la somme de ces " deux Effêts."

In *English* thus——*The Difficulty which we have hinted at, and to which the Defenders of the Opinion, that the* Force *is proportional to the Product of the Mass by the Velocity, are oblig'd often to have recourse, is built upon this: viz.* that *to have the Effect of an Effort* (that is, of a Stroke or Impulsion) *they must take away from the Effect which that Effort makes on one Side, the Effect which that same Effort makes on the opposite Side: whereas we say, that the total Effect is the Sum of those two Effects.*

There is just now come into my hands the third Edition of Professor *s' Gravesande*'s Mathematical Elements of Natural Philosophy, *&c.* in the Preface of which he gives an historical Account of the Dispute concerning the Measure of the *Force of Bodies in Motion*; which Account, for the Reader's Information, and further shewing the different Meaning that has been given to the Word *Force*, I thought fit to insert here.

Page 24. of *s' Gravesande*'s Preface to the third Edition of his *Mathematical Elements* of *Natural Philosophy, &c.* printed at *Leyden* in 1742. and the following.

The first Controversy about this Measure, tho' indirect, was between *Huygens* and the Abbot *Catalan*, on occasion of determining the Center of Oscillation.

Whoever will examine *Huygens*'s Demonstrations in the fourth Part of his Book *de Horologio Oscillatorio*, and compare them with *Catalan*'s Objections, will evidently see that in that Controversy the Measure of the Forces is treated of.

These two famous Men consider the Case in which several Bodies join'd together, descending with the Force of Gravity alone, and then loosed from one another, are carried upwards by the Velocities which they have acquir'd; or such Bodies as descend separated, and ascend together. *Huygens*, in considering this Case, reasons from this Axiom, *that Bodies cannot ascend* by the Action of Gravity; and demonstrates, that the Sum of the Products of the

 Weight

Annotat. Lect. VI. Weight of the several Bodies, multiplied by the Heights from which they fall, or to which they rise, is the same both before and after they are loosed; that is, when the Weights are separate, he seeks the Sum of the Product of the Squares of the Velocities by the Masses. (27) *Catalan* on the contrary reasons thus: " If two equal Weights suspended separately from the same Point, " [at unequal Distances] and rais'd to the same horizontal Plane, which passes " thro' the Point of Suspension, be so let fall as to describe similar Arcs—— " they will require such Velocities, that their Squares will be one to another, " as the Heights when those Weights descend perpendicular to the Ho- " rizon."

" Then, if these two Weights be join'd by a Line, or an inflexible Rod, the " which we suppose without Weight, and being suspended from the same " Point at the same Distances, they be let fall from the same Height as be- " fore; a Pendulum compounded of these will acquire as much Velocity as " the Sum of two simple Pendulums would do." And then immediately adds this Reason——" Because the Separation of the Weights does not change the " Quantity of Motion." (28)

Huygens easily demonstrated, that these Principles would lead to absurd Consequences. (29) For *Catalan* laid down with the rest, that the Quantity of Motion was proportional to the Product of the Velocity by the Mass, (which Proportion the Translation follows) but *Huygens* easily demonstrated, that *Catalan*'s Opinion that this Quantity did not change, was absurd. As to the Quantity of Motion, he had already said before, (30) what he demonstrated afterwards, (31) in the Congress of perfectly elastick Bodies, (which he refer'd to Bodies perfectly hard) that the same Quantity of Motion was not preserv'd; but that the Sum of the Products of the Squares of the Velocities by the Masses was not chang'd by the Collision, that Sum being the same before, and after the Stroke: but afterwards he spoke more generally; when he said in his last Answer to *Catalan*, *That we must by no means take for a Law of Nature, that the same Quantity of Motion was preserv'd, unless what was spent and consum'd in acting on any thing; but that this was a constant Law of Nature, that Bodies kept their ascending Force,* (Force ascensionelle) *and therefore the Sum of the Squares of their Velocities always remain'd the same.* (32) We are to observe, that this is understood of equal Masses, for *Catalan* had reduc'd the Question to this Case, as we have seen.

Before this Controversy was ended, another arose between *Leibnitz* and the same Abbot *Catalan*. *Huygens*'s last Dissertation but one was publish'd in the Year 1684, and the last, from which our Quotation is taken, was publish'd in 1690. But in the Year 1686, *Leibnitz* inserted a Paper in the *Leipzic* Acts of *March*, in which he subjoin'd these Words to the Demonstration, which he had given, and in which the Heights from which Bodies descend, and to which they ascend, are treated of. " *Hence it appears how the Force is to be estimated from* " *the Quantity of the Effect, which it is able to produce; for example, from the* " *Height to which it can raise a heavy Body of given Magnitude and Kind, and* " *not from the Velocity which it can give to a Body. . . . Therefore we must say,* " *that the Forces are in a compound Ratio of the Bodies and the Heights, from*

" *which*

"*which falling, they could acquire such Velocities. . . . . . Whence have risen* Annotat.
"*several Errors. . . . . Whence also, I imagine, that it happens, that* Huy- Lect. VI.
"gens's *Rule concerning the Center of Oscillation of Pendulums, which is very*
"*true, has of late been call'd in question by some learned Men.*"

This agrees well enough with the Words of *Huygens* which we have quoted, and which, tho' they were publish'd after what we have quoted from *Leibnitz*, only explain those Things, which are really contain'd in *Huygens*'s former Writings. Something like this often happens; so those that go before explain things so, that nothing remains for the Author of a new Invention to do, but to explain more distinctly, and declare in more express Words, what another has only hinted at more obscurely. I do not deny but that *Leibnitz* is to be esteem'd the Author of this Measure of Forces, which he explains in the Words which we have quoted from him; but I dare say, that *Huygens* led him to it.

Catalan, (33) and afterwards *Papin*, (34) answer'd *Leibnitz*: *Leibnitz* replied again, and several Papers were written upon the Subject. (35) Then many others considered the same Question.

This is what is treated of in the 2d and 3d Chapters of the second Book of this Work; I have added many new Experiments to those which I had given in the foregoing Edition. I do not contend about Words; but I have undertaken to prove and make out, by direct Experiments, these two Things, *viz.* *That Velocity is not communicated to a Body at rest, but by an Action which must be as the Product of the Mass into the Square of the Velocity. And that the Body mov'd never loses its whole Velocity, unless it overcomes the Resistance; that is, unless it produces an Effect, which follows the said Ratio.* We mean here the entire Action, and that alone, which is spent in moving the Body: and the entire Effect, and that only, which the Body produces whilst it loses its Motion. He that denies these Propositions, denies what is evident to Sight: And he that agrees to them, and yet affirms that they follow from the measure of Forces before receiv'd; I do not dispute with him: I call *Force* that Power of acting in a Body, which must be measur'd by its whole Effect, *&c.*

Now to shew how easy it is to reconcile the new and old Opinion, I will not suppress what I wrote in Defence of the old Opinion, before I was aware that the Word *Force* was equivocal; but only join'd the Word *Momentum* with the Word *Force*, to shew that we hold them as synonymous, and I do not doubt but the Favourers of the new Opinion will acquiesce in what I have alledged; considering *Force* as *Momentum* or *Pressure*, in the Sense which they give this last Word, as may be seen from N° 123. to N° 146. of the last Edition of Mr. *s'Gravesande*'s Book above-mentioned.

Here follows my Note as I first intended it.

Mr. Professor *s'Gravesande*, who had been formerly of the old Opinion, did (about 15 Years ago) come into the new Opinion; but not without having tried many Experiments with great Accuracy. What he seems to lay the greatest stress on, is, that Balls of Brass, or any other solid Substance, falling into soft Clay, make Pits in the Clay proportional to the Square of the Velocity with which they strike the Clay: the same Experiments also were made with conick

Annotat. Lect. VI. conick and cylindrick Bodies coming upon the Clay in ſeveral Directions, in all which Experiments, the Pits made in the Clay were proportionable to the Maſs multiplied into the Square of the Velocity; that is, the Maſs remaining the ſame, to the Square of the Velocity. And therefore the Profeſſor made it a Rule, that the Force of the moving Body muſt be as the Square of its Velocity; becauſe the Pits were in that Proportion. When he came to conſider afreſh the Phænomena of the Congreſs of ſoft Bodies, he found, by his way of meaſuring the Force of Bodies in motion, that the Rule generally held as an Axiom, (and which has been demonſtrated by ſeveral learned Men) *viz.* that in the Congreſs of Bodies, *there is the ſame Force* or Momentum *before and after the Stroke, towards the ſame Parts*, could not be true, but that there muſt always be Motion loſt in the Stroke by the denting in of ſoft Bodies: whereas, to make uſe of the old Opinion, which gave the ſame Quantity of Motion after the Stroke as before, was to neglect an evident Phænomenon, and admit a viſible Effect, (the denting in of the Bodies) without believing that any Part of the Cauſe was loſt in producing it. Theſe Reaſons at firſt appear'd to me ſo probable, that I was almoſt ready to quit the old Opinion; but as I could not eaſily give up what was become an Axiom, or what I had held as ſuch for many Years, and conſider'd as a Truth built on Demonſtration, I was reſolv'd to ſuſpend my Judgment till I could examine every thing a-new: and now that I have done ſo, I am ſatisfied that *there is no Force or Momentum loſt in denting in of ſoft Bodies*; and therefore, that the old Opinion ſtands good. If I can make this plain, I ſhall reſcue the Doctrine of the Congreſs of Bodies from all thoſe Paradoxes and Difficulties, which the Explanation of it, according to the new Opinion, is perplex'd with.

It has been the Cuſtom of Philoſophers that have wrote on the Congreſs of Bodies, to reaſon upon Bodies perfectly hard, (tho' there be no ſuch Bodies) becauſe thoſe Bodies can have no Elaſticity, and then to conſider how elaſtick Bodies muſt differ from them; and, in order to reduce the Doctrine to Experiments, very ſoft Bodies have been made to ſtrike each other in variety of Directions, and with equal and unequal Quantities of Matter. For it was thought, that perfectly ſoft Bodies in their Congreſs muſt have the ſame Phænomena, as to Motion and Velocity, as perfectly hard ones; becauſe, *not to be dented at all*, or *to be dented, and not have the Figure of the Bodies at all reſtor'd* in the Shock of Bodies, was look'd upon as the ſame thing in reſpect of the Motion of the Bodies after the Stroke, which then would be conſider'd as certain Maſſes of Matter without any Elaſticity, in order to ſhew how the Congreſs of ſuch Bodies would differ from that of Maſſes of Matter endued with Elaſticity. Now, tho' the ſofteſt Bodies we can get, as ſoft Clay Balls, cannot be wholly void of Elaſticity, becauſe of ſome Air that will always be in them; yet ſince that ſmall Degree of Elaſticity may be eaſily allow'd for, it was thought ſufficient to make uſe of them only in Experiments, (as we have no Bodies that approach to perfect Hardneſs) in order to ſettle Rules for the Congreſs of Bodies without Elaſticity. So it is agreed on all hands to make uſe of Bodies as elaſtick as we can get them, (ſince none are perfectly elaſtick) for ſettling Rules for the Congreſs of Bodies perfectly elaſtick, having made proper

proper Allowances for the want of perfect Elasticity. The Favourers of the new Opinion say, that we ought not to reason upon perfectly hard Bodies, because there are no such in the World. I can't blame them for not reasoning upon them themselves, because Consequences drawn from them, are contrary to the new Opinion: But it would be as unfair to debar us of that Privilege, as to say that the Science of Mathematicks cannot be true, or must not be applied to Physicks; because Mathematicians reason about Points, Lines, and Surfaces, and such penetrable Solids, as do not exist in Nature.

Now allowing me with many Philosophers to suppose Atoms, or first Particles of Matter, out of which all compound Bodies are made, to be perfectly hard; I only beg leave to reason, and draw Consequences from them.

Plate 6. Fig. 6.

Let us suppose an Atom, or perfectly hard small Body A, to move in the Direction A B, with the Velocity 12; its *Momentum* (or the Measure of its *Force*, according to the old Opinion) will be 12, which (by the *Inertia* or Inactivity of Matter) will still continue the same, unless a contrary Force should destroy it. Now let us also suppose any Number of Atoms, of small hard Bodies, having each the same Mass or Weight as A, (which Weight we will call 1) to be placed before one another in the right Line A B. (Here we are to take notice, that we have no Elasticity nor Softness to consider, only the Quantity of Matter.) A in its Motion will take along with it the Atom *a*; and dividing its Velocity with it, (the Mass being now doubled) will go on towards B with the Velocity 6, the same Force remaining after the Stroke as before, because there has been no denting in of a soft or an elastick Body to destroy any of the Force, (even according to what our Adversaries alledge) the Velocity only becoming less. When these two Atoms have in their Motion taken the third Atom *b* along with them, the Velocity becomes 4; when *c* is overtaken and carried along, the Velocity will be but 3, and so on: the Velocity diminishing in proportion as the Quantity of Matter is increased, as is denoted by the Numbers written under the Bodies. This comes to the same as if the 14 Atoms, being collected into one Body, were carried along by one Blow of A; after which we should have the same Momentum or Force as before the Stroke or Strokes, express'd at every Stroke by the same Product, tho' different Factors; for 12xby 1, is equal to $2 \times 6 = 3 \times 4$, &c. quite to $15 \times \frac{12}{15}$, and so on. If the Bodies *a*, *b*, *c*, *d*, &c. had any Velocity towards A, then indeed they would by a contrary *Force* or *Momentum* destroy Force in the Body A; but since before the Stroke there is no *Force* or *Momentum* towards A, there is no Force destroy'd in the Body A. The Velocity indeed is continually decreasing, as the Mass in motion is continually increasing by the Addition of Matter, the first *Momentum* or *Force* remaining the same. Hence it follows, that a Body infinitely small with a given Velocity will move a Body infinitely great, on which it impinges, with an infinitely small Velocity.

From what has been said it appears, that in respect of the Quantity of Motion towards B, it will be the same thing whether the Body carries all the Bodies *a*, *b*, *c*, *d*, &c. by fourteen successive Strokes, or by one single Stroke,

Annotat. Lect. VI. Stroke, if they touch'd one another before the Stroke; because the same Quantity of Matter is to be carried by A, whose *Force* or *Momentum* has been supposed 12, whether that Matter be taken at once, or at several successive times. What would happen worth Notice would be this, that if you call one Body (or a System of Bodies) the Atoms *a*, *b*, *c*, *d*, *&c.* and their Pores or Intervals the Spaces *a b*, *b c*, *c d*, *&c.* the successive Stroke will close those Intervals, and reduce that compound Body from the Position in *Figure* 6. to the Position in *Figure* 7. where the Space between *a* and *o* is shorter than it was before. If the Bodies had been at first in the Position of this last Figure, that is, without Interstices, the whole would have been a perfectly hard Body, in which case one Stroke of A had been sufficient, because all the Matter would have been taken at once.

Plate 6. Fig. 7.

Now let us suppose the Atoms *a*, *b*, *c*, *d*, *&c.* (any Number of Atoms will do, but here we will only suppose 14, that the same Numbers may serve in our Explanation) made up into a Sphere without Tenacity; which, if they could possibly hold together without Tenacity, would make a perfectly solid Sphere: And let us suppose the Atom A, without any Alteration in its Quantity of Matter, turn'd to a vertical Plane A C (see *Fig.* 8.) still moving with the Velocity 12, against the Sphere S made up of the aforesaid Atoms. As soon as A C touches the most prominent Atom *a*, it will carry it along towards B, and their common Velocity will be 6; then taking the Atom *b*, the common Velocity will be 4; taking the Atom *c*, the common Velocity will be 3; taking the Atom *d*, the Velocity will be $2\frac{2}{12}$; taking the Atom *e*, the Velocity will be 2; and so on, till A C being come to the Place D E, all the Atoms are brought into the Position DE, and have the common Velocity of $\frac{12}{15}$. For as here we have supposed no Tenacity, no *Force* or *Momentum* will be lost in bringing the Atoms into this Situation, there being only only so much Matter carried along, and the Velocity diminished in Proportion as it is distributed to so many more Atoms: and as we have supposed no Tenacity, we could suppose no Friction of the Particles among themselves.

Plate 6. Fig. 8.

Now again, let us suppose our Atoms to have Tenacity enough to make them hold together, so as to form a soft Sphere (for what are very soft Bodies but an Assemblage of hard first Particles or Atoms, that have just Tenacity enough to hold them together?) and let the Atom A (now the Body A C) in its Motion towards B (*Fig.* 9.) come upon the Sphere S; it will begin to carry the Atom *a* along with it with the Velocity 6; but it will not continue to have that Velocity till it touches *b*, because the Atom *a* by its Tenacity will take hold of *b*, *c*, and *d*, so as to have A C act upon them sooner than it would have done otherwise: the Atoms *b*, *c*, and *d*, likewise by their Tenacity bring the Parts which they touch into the Power of the Action of the percutient Body: so that long before all the Atoms are come into the same Plane, as at DE (*Fig.* 8.) all the Matter is put into motion, the Sphere being flatten'd at the Parts opposite to B. For it is evident, that if in the Beginning of the Motion of the Sphere by the Shock of A B, the Particles *a*, *b*, *c*, *d*, *&c.* have more Velocity towards B, than the Particles at

Plate 6. Fig. 9.

n, *o*,

n, *o*, the Sphere muſt be preſs'd in, dented or flatten'd at DE; which Action of yielding in will ceaſe, as ſoon as the Force of AC in motion is communicated to all the Parts. So that here the Tenacity is only the means whereby all the Particles are ſooner made to receive the *Force*, or *Momentum* of AC, than if there had been no Tenacity at all; for without Tenacity, all the Particles would not have Motion communicated to them till AC was come to FG. When the Tenacity is greater, the Body ſtricken in the Congreſs is leſs dented in, becauſe all the Matter is ſooner put into motion. If the Tenacity was infinitely great, and conſequently not to be overcome, the Motion wou'd be communicated in an Inſtant to the whole Sphere; that is, as ſoon as AC had touch'd the Particle *a*: for in ſuch a Caſe, whether the Sphere has many or few Pores, the inſuperable Contact of the Particles makes the Atoms at *n*, *o*, *&c.* move as ſoon as thoſe at *a*, *b*, *&c.* Such a Body wou'd be a perfectly hard Body, concerning which I hope my Reader is ſatisfy'd by this time that it is fair to reaſon; as well as concerning perfectly ſoft Bodies, which no more exiſt in Nature than perfectly hard ones. All the Bodies that do exiſt, and which we make uſe of in Experiments, are more or leſs ſoft according to their greater or leſs Tenacities.

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Plate 6. Fig. 9.

The ſame Reaſoning that we have uſed for explaining the denting in of a ſoft Body ſtruck by one overtaking it, will ſerve to explain the Cauſe of the denting in of a percutient ſoft Body; for as the antecedent Parts of it ſtrike the Body they come againſt, ſooner than the conſequent (or hinder) Parts of the Body do, their Velocity diminiſhes ſooner, and continues diminiſhing till all the Parts of the percutient Body come to act on the Body which they ſtrike: And what elſe will the Diminution of the Velocity of the anterior Parts of a moving Body faſter than the poſterior Parts of it do, but produce a Change of Figure, which is the denting in of the ſtriking Part of the Body?

I ſhall ſay nothing here of the Congreſs of elaſtick Bodies; becauſe if I have ſufficiently ſhewn, that the Phænomena of the Congreſs of ſoft Bodies can beſt be explain'd according to the *old Opinion*; it will naturally follow that the Congreſs of elaſtick Bodies muſt be explain'd by it.

As I am now enter'd into the Conſideration of the old and new Opinion concerning the Meaſure of the Force of moving Bodies, and have promiſed in my firſt Volume to ſpeak fully of it in the ſecond; I ſhall here go on with it, by removing the ſtrongeſt Objections that were made againſt the Experiment of the flat Pendulum deſcribed in my firſt Volume (ſee *Page* 394, and 11. and *Plate* 24. *Fig.* 1.) becauſe I have heard of ſtronger Objections ſince. Laſt Year looking over ſome Papers, I found a Letter from that excellent and accurate Philoſopher, the Profeſſor *Petrus van Muſchenbroek*, whoſe Objections I thought ſo ſtrong that they very well deſerved Notice. Upon that I anſwer'd them in a *Latin* Letter that I wrote to him then; and as it is now agreeable to my preſent Purpoſe to ſay the ſame things that I ſaid in my Letter, I ſhall here give a Tranſlation of ſo much of that Letter as relates to the Queſtion in hand, tho' in ſome Places I only repeat ſome of the above Arguments in other Words.

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Vol. I. Plate 24. Fig. 1.

" In order to call to mind my Experiment, open my Book (Vol. 1.) and " cast your Eyes upon the first Figure of Plate 24. The flat Plate ABCD " being suspended by four Strings, and raised up from its lowest Place to- " wards *ε* to Number 12, is suddenly let down to vibrate: mean time the " Weight W is made to fall upon the Plate, while it is at the lowest Place " of its Motion, or the Middle of its Vibration, and the Body compounded " of the Plate and Lead W, is carried to the Degree 6 towards F. The Rea- " son why this double Mass did not go to the Degree 8,48 + as it ought " to do according to your Opinion, you alledged was the Friction; your " Words are these: If *yours be the right Estimation of the Forces, whence does* " *it happen that the Mass goes quite up to the 6th Degree? Has Friction no-* " *thing to do here? Here is an evident Cause, where is the Effect? How little* " *soever this Cause may be, it shou'd take away something visible from the Ve-* " *locity* 6. I confess that this Objection put me to a stand at first; but, ha- " ving consider'd the thing well, I answer, That there is no Friction at all " in this Case: and that the Cause being taken away, there can be no Effect " produced. You'll certainly wonder at what I say! But read patiently " while I explain this Paradox in a few Words. By the Threads *pppp* " (*Plate* 6. *Fig.* 10.) let the above described Plate ABCD weighing two " Pounds be suspended, whose Under-side has a Tooth or Semi-cylinder *e*, " whose Axis is perpendicular to the Line AB. Let there be also a Paralle- " liped RR of two Pound weight, having a-cross its Surface Teeth, or se- " mi-cylindrical Eminences *a b c d*; and let this Parallelipiped be immoveable " in its Place. Now if the Plate be let down from the 12th Degree mark'd " upon the graduated Arc that is set under its Vibration, the Tooth *e* meet- " ing with the Teeth *a*, *b*, *c*, *d*, suffers a Resistance, but overcomes it by the " Force of the moving Plate, and this jumping of the Plate retarded by " this Resistance, is called its *Friction*. Now this Friction hinders the " Plate from rising up to 12 on the opposite side. But if the Parallelipiped " be made in another manner, having its Teeth moveable, and to go down " into Cavities (such as are mark'd by the Points in the Figure) only made " to stand up a little above the Surface *n* R by the Force of the Springs, " S*s*, S*s*, S*s*, S*s*; then if the Plate be let down from the 12th Degree " whilst it runs over the Surface *n* R, it will by its Tooth *e* successively push " down the Teeth *a*, *b*, *c*, *d*, by which Resistance being retarded, it will not " reach the 12th Degree of the graduated Arc. This is a Friction of another " kind. Neither is there any other Friction but of these two sorts, both which " are capable to tear away small Parts from the Bodies rubbing; for Bodies that " run over the Surface of other Bodies, do either pass over stiff Eminences by " jumping, or do depress elastick ones by the Force of their Motion, and lose " of their own Motion in proportion to the Effect produced. You will easily see " that no such thing happens in my Experiment, by supposing the following " Experiment. Let the Parallelipiped aforesaid, be suspended by Strings, so " that it may easily vibrate in an Arc parallel and a little below the Arc in " which the Plate vibrates. Now if the Plate be let down from the 12th De- " gree, its Tooth E falling against the Tooth A of the Parallelipiped will not

Plate 6. Fig. 10.

" jump over it or press it down, but carry the Parallelipiped along with it, " and the Body compounded of the Plate and Parallelipiped, will only go " forward to the 6th Degree. In this Case there is no Friction, but only an " Accession of Matter to the first Mass. Here I say nothing of the Stroke " of the Body *w*, when it falls on the Plate, (see *Plate* 24. *Fig.* 1. of my " 1st Volume) because I have there explain'd the Effect of such a Blow; and " also described how the Experiment is made without the falling of the Body " W: But there I did not mention that I had wrapped round with wet " Sheep's Leather the Weight W, that was to be taken hold of by the mo- " ving Plate, lest the Experiment should be disturbed by the Elasticity of " the Half-Cylinder fix'd to the Plate. Now let us change this imaginary " Friction into a Stroke made on a soft Body, in which Body it will cer- " tainly be seen, as from its Point of Rest it is taken and carried along by " an upright Plate fix'd perpendicularly to the vibrating Plate above men- " tion'd; the compound Mass of the Plate and soft Body going to the De- " gree 6, when the Plate before the Stroke came down from 12 on the other " side.

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Plate 6. Fig. 10.

" LET PP be the Plate weighing 36 Ounces, with its perpendicular " Piece V fix'd on purpose to strike the Body *a*BC made of soft Clay, hang- " ing by the Thread 2, which Body likewise is of 36 Ounces weight, (see " *Plate* 6. *Fig.* 11.) now I say that the Plate falling from the 20th Degree, " taken beyond E, will in its Motion take the Ball *a*BC along with it, and " rise up to 10 on the opposite Side. This you also agree to, but you ask, " *Whether the Plate won't change the Figure of the suspended Body, make a* " *Pit in it, and remove the Parts from one another. Can that be done without* " *a loss of Force and Motion in the Plate?* Yes, that can be done without " any loss of *Force* or *Momentum* in the whole Mass, tho' there be a loss of " *Force* in the Plate taken singly; and that happens by a Translation of Ve- " locity from the Plate into the Ball. And in the Congress of pendulous " Bodies, there is always the same Quantity of Motion towards the same " Parts after the Stroke as before. This I know you don't believe; but I " hope to explain you this Paradox, if you will but for Argument sake sup- " pose our Rule to be true; for these Phænomena will be deduced from it.

Plate 6. Fig. 11.

" LET the Ball *a*BC be divided into three equal Parts *a*, B, C, and sus- " pended by the different Threads 1, 2, 3. First, let only the Part *a*, of 12 " Ounces, be suspended at rest above O, the lowest Point of the Vibration: " then let the Plate fall from the Degree 20, and it will take along with it " the Clay *a* up to the Degree 15; for the Force of the falling Plate $= 36 \times$ " $20 = 720$, being divided by the Mass $36 + 12 = 48$, will give for its " Quotient $\frac{720}{48} = 15$. If the Experiment be made by suspending at the " Point of Rest the Parts *a* and *b*, whose Weight taken together is 24 " Ounces, the Plate falling from 20 will carry the whole Mass along with it " to 12; for the Momentum 720 being divided by $36 + 24 = 60$ will give " 12 for Quotient. Lastly, the whole Ball suspended, and struck by the " Plate falling from the same Height will go to the Degree 10, because $36 +$ " $36 = 72$, dividing 720, will give for Quotient $\frac{720}{72} = 10$. Now by the

 " Inertia

Annotat. Lect. VI. Plate 6. Fig. 11.

" *Inertia* of Matter in the Ball, or rather of the Parts which make up the " Ball, the Plate cannot in one Moment of Time communicate Motion to all " the Parts of the Ball, but takes along with it first the Parts next to it, and " then the middle ones; and lastly, the Parts that are the most remote. " Now to the first Parts as *a* does belong (or must be communicated, accord- " ing to our Rule) the Velocity 15; to the middle Parts, as to the Part " *b*, the Velocity 12; and to the remotest Parts, as to the Part *c*, the Velo- " city 10: for the Velocity 20 of the Plate is not diminish'd quite to the Ve- " locity 10 before all the Parts of the Ball are carried along: for the Motion " must be equally distributed thro' the whole Mass, that the Velocity may " decrease in a reciprocal Ratio of the increas'd Mass. Now if the Part *a* " comes towards F with a greater Velocity than *b*, and the Part *b* with a " greater Velocity than the Part *c*, as must happen by what has been said, " what is that Phænomenon else but a Change of Figure, especially if we rea- " son concerning a Globe divided into an infinite number of Parts; and " then the Velocity will decrease in a Series whose greatest Term is 20, " and the least 10, and the Decrements will be reciprocally proportional " to the Matter successively added to the moving Plate.——Thus will " the Expression of the Velocities be 20 — 1, 20 — 2, 20 — 3, &c. " quite to 20 — 10 = 10. Here perhaps you will object, that I did " not consider the Cohesion or Tenacity of the Particles: but now let us " consider it. If the Tenacity was infinite, then the Motion would be com- " municated to the whole added Mass by the Blow, without any Change of " Figure; for then the Body would be a perfectly hard Body, and the first " Particle would be so join'd with the last, that they would move together, " and receive their Motion at the same Moment of Time. All that the Co- " hesion does, such as it is, is only this, that thereby the Motion of the first " Part is sooner communicated to the second; the Body as it were coming " nearer to Hardness without Elasticity. I made the Experiment again with " the three Parts of the Ball *a*, *b*, *c*, suspended all together at the same time, " but at a little distance from one another, and the Success prov'd the same. " Then I made the Experiment in another manner, and instead of the Piece V, I " fix'd to the Plate the hollow Half-Cylinder, (described in my Book, *Vol.* 1. " *Plate* 24. *Fig.* 1.) and instead of the Clay Ball, 18 Leaden Bullets suspended by " Threads, which Bullets all together weigh'd 36 Ounces; and the Experiment " succeeded in the same manner. I also made the Experiment with a Plate, and " the Bottom of the Lead, both polish'd; in which Case, the Plate falling suc- " cessively from the Degrees 24, 20, 12, carried the Lead receiv'd at bottom " to the opposite Degrees 10, 12, 6. In the Experiment thus made there " was only this Variation; namely, that when the Lead was not receiv'd in " the middle of the Plate, or after its Reception slid a little, the Center of " Gravity of the Mass was not in the middle; whence it happen'd that the " Edge of the Plate, which was farthest from the Lead, did go a little be- " yond the Degree expected; but in recompence, that which was nearest the " Lead came as much short of the opposite Degree. Now let us consider the " Congress of two Balls of soft Clay. I have already explain'd whence

" comes

" comes the Change of Figure in the Ball that was at reſt before the Stroke. " In the percutient ſoft Body the Change of Figure happens, becauſe its fore-" part, which in the Motion of the Ball before the Stroke had the ſame Ve-" locity as the hinder Parts, is retarded at the Stroke in proportion to the " communicated Velocity, whilſt the hinder Parts, by reaſon of the *Inertia* " of Matter, (whereby Matter in Motion endeavours to perſevere in the ſame " State) do more ſlowly loſe their firſt Velocity: and a Body, whoſe fore " Parts move ſlower than its hinder Parts cannot but change its Figure."

What follows in the Letter is much the ſame as I ſaid at the Beginning of this Annotation; but at laſt I concluded with mentioning an Experiment, which I think proper to relate here in the ſame Words.

" If yet you have any Doubt remaining concerning the Concluſions de-" duced from my Experiment above-mentioned, give me leave to detain you " ſo long, as to relate to you my laſt Experiment. I do not doubt but that it " is agreed between us, that the perpendicular Stroke of the Body (falling on the " ſwinging flat Plate) does nothing towards retarding the horizontal Motion, " if we conſider only the Stroke. For by the Compoſition of Motion which " makes a Body, acted upon by two Forces, move in the Diagonal of a Paral-" lelogram, the thing is plain; as I demonſtrated it in my Book. My laſt " Experiment, which I hope may be call'd an *Experimentum Crucis*, is as fol-" lows. I dropp'd upon the vibrating Plate, which fell from the 20th Degree, " a Ball of ſoft Clay of the ſame Weight as the Plate at the loweſt Part of the " Vibration, and the compound Maſs went up exactly to the 10th Degree on " the other ſide. Here the Change of Figure in the Ball was made by the " Plate in a Line perpendicular to the Direction of the Motion of the Plate, " which could do nothing but affect the Strings by which the Plate hung, by " ſtretching them. For if, according to your Objection, the Change of Figure " in the horizontal Stroke retarded the horizontal Motion; here the *Force*, or " *Momentum*, diminiſh'd by no ſuch Impediment, muſt have carried the whole " Maſs beyond 10, (according to the new Opinion) which never happen'd."

Notwithstanding what I have ſaid is true; it is eaſy to reconcile this Phænomenon to the new Opinion, both by a further Experiment on this Machine, and by Reaſoning.

Experiment I. *Plate* 6. *Fig.* 11.

Let us ſuppoſe at one End of the flat Pendulum, that a Cone of Braſs is faſten'd, which, together with the upright Piece V, does not make the whole Machine P P *g* V heavier than 3 ℔; then raiſing this Pendulum up to N° 20, on the graduated Arc, let it fall, ſo that when the Part V is over O, the Cone ſhall ſtrike againſt a Body of Clay made faſt in the Cavity of a Box fix'd at *g*, and obſerve what Pit is made by meaſuring it. Suſpend the Clay Ball *a*, *b*, *c*, as before: ſo that P V P being again let fall from N° 20. may take the Clay Ball along with it, before the Cone ſtrikes into the Clay, (of which another Part is expos'd to the Stroke) and you will find the Pit made by that ſecond Stroke to be only half of what the former Pit was. Hence it appears, that the ſame Momentum makes different Pits; but with different *Force*,

taking

Annotat. Lect. VI. taking *Force* in the Sense of the new Opinion; in which Sense, the Plate has spent half its *Force*, (tho' without any Loss of Momentum, as we have amply shewn) in taking along the Clay Ball, and the other Half in making the Pit in this second Experiment; whereas it spent its whole *Force* in making the Pit in the first Experiment.

N. B. I own I have not made these two last Experiments myself; but I have deduced from Messieurs *s' Gravesande*'s and *Muschenbroek*'s Experiments, that they must certainly succeed in this manner.

I SHALL mention but one Experiment more in favour of the old Opinion, which seems liable to no plausible Objection.

EXPERIMENT II. *Plate* 7. *Fig.* 1.

To the horizontal Board G G, screw'd up to the Cieling of a Room, I fix'd four small Strings *a* C *b*, *c* C *d*, *c* D *f*, *g* D *h*, which Strings passing thro' four Eyes in the Studs C, C, D, D, held in an horizontal Position, at the Distance of 14 Foot below G G, the two Iron Cylinders A and B, one of which, B, is a little Gun having a Cavity or Bore at E, with a Touch-hole at H, and a Nose to go into the other Cylinder at F, (as is represented in *Fig.* 3.) that when both the Cylinders are suspended, they may hang together like one Piece, because the Distance A B, being greater than the Distance *a h* of the Strings above, the two Parts A and B are held together by their Weight, tho' the Nose of B goes so easily into the Cavity of A, as to have no Stickage or Friction. The Part A may be seen at Figure 2, and the Part B at Figure 3. A and B are exactly of the same Weight; but upon Occasion the Part B may be made twice as heavy as A, by slipping on the hollow Cylinder represented by Figure 4 over the Part B, the Hole or Cavity L M being big enough to slip over the Part B, whilst the Slit L L suffers the Studs D D to pass by. N. B. *The Ends* A, B, *and* N, *are made conical*, to pass thro' the Air in their Motion with more Facility. The Experiment to be made with this Machine is as follows: Fill the Cavity E of the Part B with Gun-powder, and prime it at H, (see *Fig.* 3.) then having set under the united Cylinders the graduated Arc O P, so that o Degrees may be under the Place where the Cylinders join, set fire to the Gunpowder by means of a salt-peter'd Thread laid over H, and the Parts A and B will fly from each other towards O and P to equal Distances, as may be observ'd by the Degrees mark'd on the Arc or Scale O P. Care must be taken in fixing the Strings that the upper Ends of each String, as *a* and *b*, *c* and *d*, *&c.* may be at least at 9 or 10 Inches from each other, measur'd a-cross the Board G G; because otherwise A and B would not move both in the same Plane, and over the graduated Arc below. When the Part L L M N is put on over B, and B is charg'd and fir'd, it recedes but to half the Distance towards P that A does towards O; which shews, that since the Powder in its Explosion acts equally on the two Parts, and gives them equal *Forces* or *Momenta*, the *Forces* or *Momenta* must be measur'd by multiplying the Bodies into their Velocity, which here are reciprocally as the Masses. It is indeed difficult to charge the Cavity E so exactly as to make the Bodies recede as far in one Experiment as in another; but, whatever be the Force of the Explosion,

Plate 7. Fig. 3.

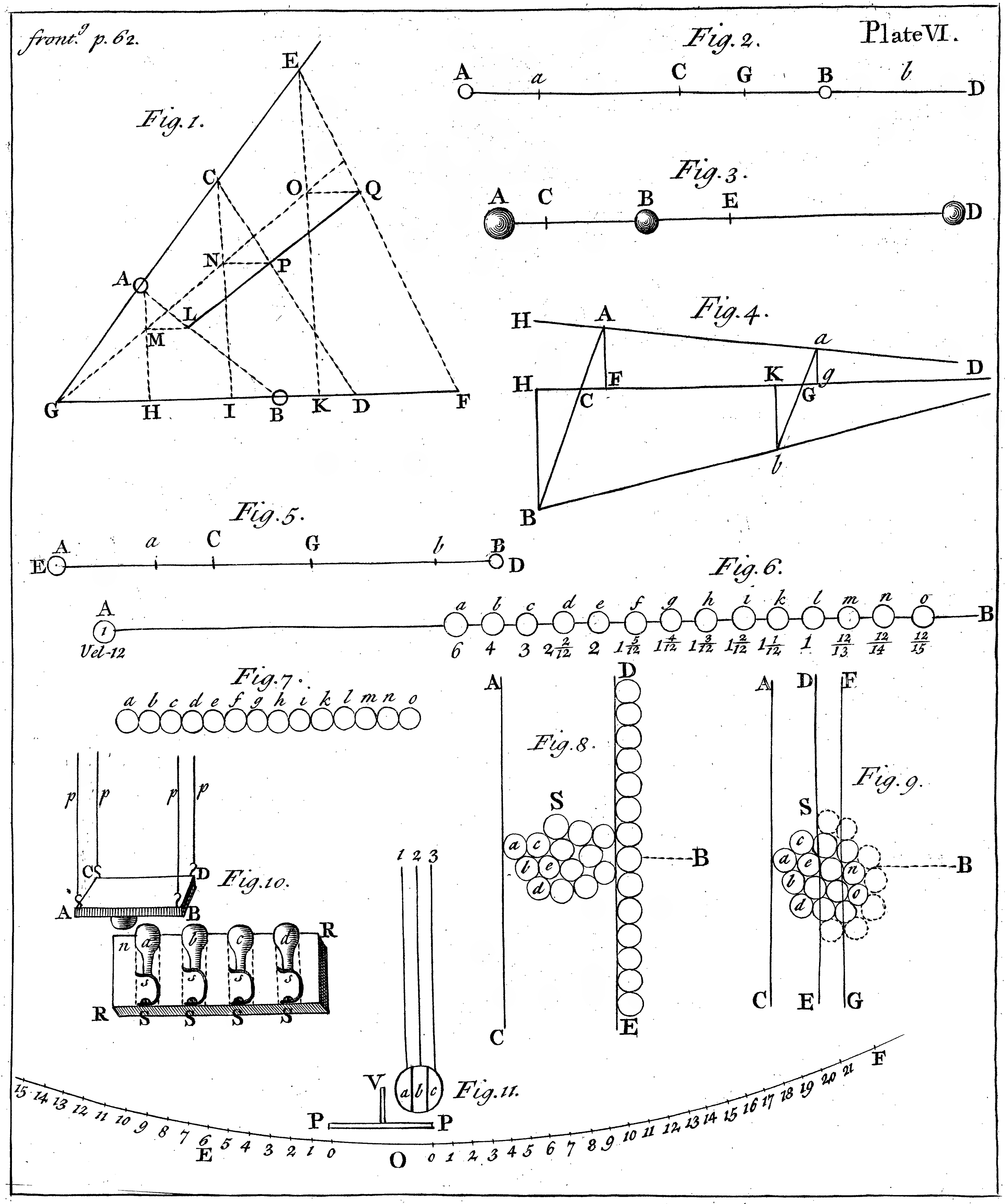
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Plate VI.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Vel-12
6 4 3 $2\frac{2}{12}$ 2 $1\frac{5}{12}$ $1\frac{4}{12}$ $1\frac{3}{12}$ $1\frac{2}{12}$ $1\frac{1}{12}$ 1 $\frac{12}{13}$ $\frac{12}{14}$ $\frac{12}{15}$
Fig. 7.
a b c d e f g h i k l m n o
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.

Exploſion, whether greater or leſs, A is always ſhot towards O twice as far as B (when L M N L is added to it) is ſhot towards P. Annotat. Lect. VI.

THERE is no calling in queſtion, that the Preſſure made by the Gunpowder, gives equal *Momenta* to unequal Quantities of Matter, by giving them Velocities reciprocally proportionable to thoſe Quantities of Matter: neither is there any doubt (in favour of the new Opinion) that Pits made in Clay by the Bodies driven by the Gunpowder (ſuppoſing the Clay fix'd at A and B, *Fig.* 1.) will be to one another as 1 to 2, when the Bodies are as 2 to 1; 2 with half the Velocity making only a Pit as 1, when 1 with the double Velocity will make a Pit, as 2. This ſhews, that the Force may be double or half, when produc'd by a Body with the ſame Momentum, when the Velocity differs.

As I am now convinc'd that all the Phænomena of the Congreſs of Bodies may be equally ſolv'd according to the Principles of the Defenders of the new, as well as thoſe of the old Opinion, I ſhall here give an Example of four Experiments, where all their Phænomena will be ſolv'd both ways.

EXPERIMENT III. *Plate* 7. *Fig.* 5.

SUSPEND two equal Clay Balls (for example, weighing two Ounces each) by Strings from the ſame Height on the Machine for trying the Congreſs of Bodies. Then let the Body A be rais'd up from the loweſt Point, ſo as to let it fall towards C with ſix Degrees of Velocity, to overtake the Body B falling the ſame way with two Degrees of Velocity; and the Stroke being made at the Bottom, they will both go on together with four Degrees of Velocity, as may be obſerv'd by their going up to Number 4. Now here before the Stroke, the Momentum of A being 12, and the Momentum of B being four, the Sum of the Momenta towards C is 16; which appears to be the ſame after the Stroke; for the Stroke does not diminiſh the Momentum, for the Reaſons which I have alledged.

BUT, according to the new Opinion, the Force of A is 72, which being added to 8, the Force of B, makes 80 for the whole Force: then after the Stroke, becauſe the two Bodies go on with the common Velocity 4, their Force muſt be 64, ($4 \times 4 \times \overline{2 + 2} = 64$) which, taken from 80, leaves 16 for the Force loſt in denting the Bodies.

EXPERIMENT IV. *Plate* 7. *Fig.* 6.

LET the Body A, with ſix Degrees of Velocity, go towards C, and the Body B go in a contrary Direction towards A, with two Degrees of Velocity: after the Stroke the Bodies will go on together towards C, with two Degrees of Velocity.

THE Momentum of A towards C is 12; from which ſubtracting 4, the Momentum of B towards C, there will only remain 8 for the Momentum of the Bodies towards the ſame Parts. But ſince the Velocity of the two Bodies towards C is but 2 after the Stroke—it follows, that the Momentum is the ſame, both before and after the Stroke. This agrees with the old Opinion,

which

Annotat. Lect. VI. which ſays, the *Force is the ſame before and after the Stroke*, when *Force* is taken as ſynonymous with *Momentum*.

Plate 7. Fig. 6. According to the new Opinion, the Force of A being 72, is to be added to the Force of B, which is 8, (notwithſtanding that B acts in a contrary Direction) the Sum of the Forces being always taken, inſtead of the Difference, whatever be the Direction; and then the whole Force will be 80. After the Stroke, as the common Velocity of the Bodies is but 2, the Force left in them will be but 16; which being taken from 80, leaves 64 for the Force ſpent in denting the Bodies.

N. B. Here it appears according to both Opinions, that in the Congreſs of equal unelaſtick Bodies, the common Velocity after the Stroke will be equal to half the Sum of the Velocities of the Bodies before the Stroke, if they go the ſame way; and half the Difference of the Velocities they had before the Stroke, if they go different Ways. And likewiſe, the Velocity after the Stroke will be equal to half the Velocity of the percutient Body, if one of the Bodies was at reſt before the Stroke.

Experiment V. *Plate 7. Fig. 7.*

Plate 7. Fig. 7. Let A ſet out with the Velocity 8, and ſtrike B, which is at reſt; and both Bodies will go on with the Velocity 4.

Here the Momentum before the Stroke wholly in one Body is 16; and the ſame after the Stroke, when both Bodies move, the Velocity decreaſing in proportion to the additional Quantity of Matter taken along by the Body in motion.

Considering this in the way of the new Opinion: The Force of A before the Stroke is 128: but after the Stroke it is only 64, as the two Bodies go together. From whence it follows, that the Force ſpent in denting the Bodies muſt be 64. If we compare this with the Experiment of Figure 6, we ſhall have a Paradox, or ſeeming Contradiction; becauſe in this the whole Force, as 80, produces as great a Shock; that is, the ſame denting in of the Bodies, as the Force 128 in *Fig.* 7. But this will be ſolv'd by conſidering that the denting in of the Bodies is according to the Square of the reſpective Velocity of the Bodies, which is the ſame in the Experiments of *Fig.* 6. and *Fig.* 7.

Plate 7. Fig. 8. This is confirm'd by the Experiment of *Fig.* 8. where the ſame Force is ſpent in denting in the Bodies, as in *Fig.* 1. *viz.* 16 Degrees of Force; tho' before the Stroke the whole Force was 80 in the Experiment of *Fig.* 1. and only 32 in the Experiment of *Fig.* 8. But the reſpective Velocity was the ſame, and conſequently its Square, which the denting in of the Bodies is proportionable to.

Corollary.

Hence follows, that the whole Effect of the Forces is conſider'd in every Caſe, whether they act in the ſame or in contrary Directions. Whereas the Momenta are only conſider'd as the Quantity of Motion towards the ſame Parts; adding them when the Bodies have the ſame Directions, and ſubſtracting the leaſt from the greater when they have contrary Directions.

To

To set this matter still in a clearer Light, I will here give by way of Example what has been written by two Authors, the one in Defence of the Old and the other in Defence of the New Opinion, with my own Remarks upon each of them. The first is so much of a Manuscript Paper of Mr. *Colin Mac-Laurin*, (Professor of Mathematicks at *Edinburgh*) called *a Treatise of Motion from Impulse*, as relates to the Measure of the Force of Bodies in motion, which, while we consider the word *Force* as an *instantaneous Pressure*, and synonymous with *Momentum*, is unanswerable in Defence of the old Opinion. But I have taken the liberty, by marginal Notes, to shew that all that he says may well be allow'd as true, without any way overthrowing or disproving any thing of the New Opinion: provided Mr. *s'Gravesande*'s Explication of the word *Force* (that is, the same as many Authors on that side have given for the Definition of it) be considered all along.

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This Paper was given me a few Years ago, by the late Mr. *Charles*, a Mathematician in *London*, who, at my desire begg'd leave of the learned and ingenious Professor that I might publish it, and acquainted me that I might do so.

Mr. Professor MAC-LAURIN's Dissertation; that is, so much of it as concerns *The Measure of the Forces of Bodies in Motion.* *

62. It was generally allowed, that the Forces of equal Bodies moving with different Celerities, were in the same Proportion as these Celerities, till Mr. *Leibnitz* disputed this about the Year 1686, and advanced, that the Forces of equal Bodies were in the Proportion of the Square of the Velocities †. He has of late been follow'd by some celebrated Philosophers in several Parts of *Europe*, who have advanced for his Doctrine some Reasonings and Experiments more ingenious perhaps than those he himself produced for it. As this is the Question most disputed on this Subject, we shall consider it fully; and first propose the Arguments which seem to demonstrate the ancient Opinion, and then endeavour to consider impartially what has been advanced against it by those Authors.

63. IN the first place it has been universally allowed, that in the Collision of Bodies, Action and Re-action are equal, and the Favourers of the new Opinion own that the Force gain'd in a Collision by one Body, is lost by the other, and conversely what is lost by one is gain'd by the other. Let us therefore examine which Measure will best agree with this Principle, and because some of the Authors who stand for the new Opinion, refuse to allow the possibility of the Existence of hard Bodies, let us examine it of those that are perfectly elastick. Some things we shall be obliged to suppose will be such as are allow'd by both sides.

* NB. *The Articles from the Beginning to N° 61. are foreign to our Purpose, and therefore we only begin at* N° 62.

† Here begun the Misunderstanding, &c.

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Plate 7. Fig. 5.

64. Suppose with them that the Body A moves with a Velocity V, and by the Intervention of Springs begins to act on the quiescent equal Body B; then since the Springs add to B the Force which they subduct from A, whatever Force is taken from A (*Plate* 7. *Fig.* 5.) ought to be found accumulated to B: but it is certain that when the first Period of the Action of the Springs is over, that is, when they are brought to their greatest Compression, the Velocity of A is reduced to half of what it was at first, that is, to $\frac{1}{2}$V, and the Velocity of B being equal to that of A in this Moment of Time (the respective Velocity of the Bodies being then destroy'd) must be equal to the same. The Force of A, according to the new Opinion, was at first V V, and is now $\frac{1}{2}V \times \frac{1}{2}V = \frac{1}{4}VV$, and therefore the Force which A has lost, must be $\frac{3}{4}$VV. The Body B has acquired a Velocity $\frac{1}{2}$V, and therefore, according to their Measure, a Force $\frac{1}{4}$VV, which is but the third Part of what A has lost, *viz.* $\frac{3}{4}$V V. Therefore according to their Measure of Forces, Action and Re-action are not equal, since the Body B acquires but the third part of what A has lost; whereas, according to what we cited from a learned Author that maintains the new Opinion, [in *Art.* 47.] the Diminution or Augmentation of the one, is the immediate Effect of the same of the other, and the Sum of the Forces ought not to suffer the least Change from the mutual Actions of the Bodies. After the same manner it may be shewn, that in any other Moment of Time during the Actions of the Bodies upon one another, the Force acquired by B, is less than the Force lost by A, according to their Measure of Forces, till at length the Action ceases, when according to either Measure, the Force of B is found equal to the Force which A has lost. *

65. If the Bodies be unequal, it will be found still that the Force gained by B in any point of Time before the Action of the Bodies is over, is less than the Force lost by A, according to their Measure of Force. † If A be less than B, it will be reflected backwards, but there is a Moment in which the Force of A is destroy'd by the Action of the Springs, before they begin to imprint on it a Motion in a Direction contrary to that of its first Motion. In that Moment the whole first Force of A ought to be found in B ||, and after that Moment the Force of B, by the Action of the Springs ought still to increase, and therefore become greater than the first Force of A; but according to the Measure of Forces which these Authors contend for, the Motion of B is always less than the first Force of A, even after the Action is over. According to their Measure you must add to the Force of B, that with which A is reflected, to make a Sum equal to the first Force of A. ‡

66.

* This Reasoning is not conclusive till the Springs have done acting; and then it will suit both Opinions. The Velocity multiplied into the Mass being as the Momentum, and the Square of the Velocity multiplied into the Mass being as the Force.

† Part of the Force lost is in the Springs, while they are still bent.

|| Not in B alone, but in the Springs and B.

‡ So you must; because the Sum of all the Actions in any Direction is their way of Measuring, call'd the whole Effect: which the old Opinion only makes the Difference of Momenta.

66. Their Estimation of Forces therefore cannot be reconciled with the Equality of Action and Reaction, or with the Preservation of the Sum of the Forces measured in the same Direction, its plain Consequence **. They indeed maintain the Preservation of the same Quantity of absolute Force; but have given no Reason for it. They must understand Action and Re-action in a manner not yet explain'd to reconcile it with their Doctrine, and deduce from it the Preservation of the absolute Quantity of Motion in the Action of Bodies †*. It will no doubt be denied by some, that the Springs add to B, all that they subduct from A; who will pretend that a part of the Force of A is employed in compressing the Springs, which is again restored to the Bodies on their expanding themselves? It cannot be denied but that Force is always required to compress Springs, and consumed in doing it; but it appears very evident, that when Springs are compress'd, they must endeavour to expand themselves with a Force equal to that with which they are compress'd, and therefore whatever Force is employed in compressing them, and by the Resistance of the Springs lost to A, in producing that Effect must be communicated to B, by the equal Action of the Springs upon it ||*. There is nothing detracts from A, but the Resistance of the Springs, and the equal Action of the Springs in the opposite Direction, must add as much to B in every Moment ††. To make this more plain, suppose the equal Bodies A and B to act on the Springs in opposite Directions with equal Forces, and they will compress the Springs, and by so doing, lose their Forces in the same Degrees, till both their Motions be destroy'd. Now in this Case, the Force of A compresses the Springs, and the Springs acting on B, take from it as much Force as A exerts upon them. The Force lost by A at any time, may therefore be measured by the Force which is taken from B, or by the Compression of the Springs from A to C, but it would be manifestly wrong to measure the Force which A loses by both these Forces; for it would be to take it twice into the Account *. In the same manner the Force which A loses [in the 64th Article] may be measured by the Quantity of Force it has exerted, in compressing the Springs, or the Quantity of Force which the Springs have communicated to B; but it appears very unreasonable to suppose it equal to both.

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Plate 7. Fig. 5.

67. I know no Principle more manifest that can be advanced concerning Motion, than that equal Pressures or Impulses in equal Times, must generate or destroy equal Forces; certainly one who disputes this, means something by Force that has never yet been explain'd, and perhaps cannot.

Now I find that the present Vouchers of this new Doctrine allow, that two Bodies A and B ‡, moving in opposite Directions with Velocities reciprocally

 pro-

** See the last Note.

†* They are equal at the End of all the Action; because the Action takes up Time like an absolute Number equal to a Series.

||* And so it proves when they have done acting.

†† Not every Moment, but before they have done acting.

* No, it is taking the whole Account.

‡ They deny it. See *s'Gravesande.*

Annotat. Lect. VI. Plate 7. Fig. 5. proportional to their Quantities of Matter in acting on the Springs, exert equal Effects, and meet with equal Resistance from these Springs, and lose their Motion at once; than which I know not any thing that can shew more evidently that these Forces must be equal. In like manner if the Springs after the Forces of the Bodies are destroy'd separate them, it is allowed that they will generate in the same time in them Velocities reciprocally proportional to their Quantities of Matter; it is also allowed that the Springs will exert equal Efforts upon them *, from which it seems plainly to follow, that the Forces are equal when the Velocities are reciprocally, as the Quantities of Matter in the Bodies; and therefore the Forces of Bodies must be estimated by the compounded Ratio of the Quantities of Matter and the Velocities †. I know that these Authors infer from the Bodies meeting one another in C, (so that A only describes the Line CA, and compresses only the Springs from A to C, while B describes the Line C B, and compresses all the Springs from C to B) that their Forces must be in the proportion of CA to C B. But I know no Reason that ever was given for measuring the Forces by the Number of Springs that act upon Bodies, rather than the Efforts which it is allow'd these Springs exert ‖. But of this afterwards. I shall only observe at present, that in Philosophy it must be allow'd that a Force is equal to the Sum of all the Impulses or Efforts that are employ'd to generate it, as in Geometry, That the Whole is equal to all the Parts, since it is the Accumulation of these Efforts constitutes the Force ‡ of the Body.

68. In the next place, the new Doctrine is inconsistent with the Principles establish'd. For if the Measure of Forces which these Authors wou'd establish is just, the Actions of Bodies must be very different in a Space that is mov'd with an uniform Motion forwards, and in a Space that is at rest. Let the Space EFGH move with a Velocity as *one* in the Direction E F, and suppose the Body A to be moved in the Space by means of Springs, or by any other Influence by a Velocity as *one* in the Direction of the Motion of the Space, so that its Velocity in absolute Space may be as *two*. The Action of the Springs raise (according to the new Opinion) the Measure of the Force of A from 1 to 4, these being the Squares of the Velocities which are as 1 to 2. The Springs therefore add to the Body a Force as 3; whereas had the Space been at rest, the Springs had imprinted on the Body a Velocity as 1, and a Force as 1 also. It is plain therefore that the same Springs or Agents exerting the same Force do not act †† in the same manner on the Body A, when the Space is at rest, as when it is carried on with an uniform Motion, if their Doctrine is true; and yet this has

Plate 8. Fig. 1.

* The Author of the Discourse *sur le Mouvement,* cited above, begins the State of this Case thus: *Supposons deux Corps en repos* A & B, *entre les quels est un Ressort bandé* C, *qui commençant à se debander fasse un Effort de part & d'autre pour éloigner l'un de l'autre les Corps* A & B.

† They deny it. See *s'Gravesande.*

‖ Their Definition is, that the Force is equal to the Number of Springs that can be bent.

‡ When by *Force* is meant *Momentum.*

†† It does act in the same manner, producing the same Velocity; whence arises a Paradox prov'd by Experiment.

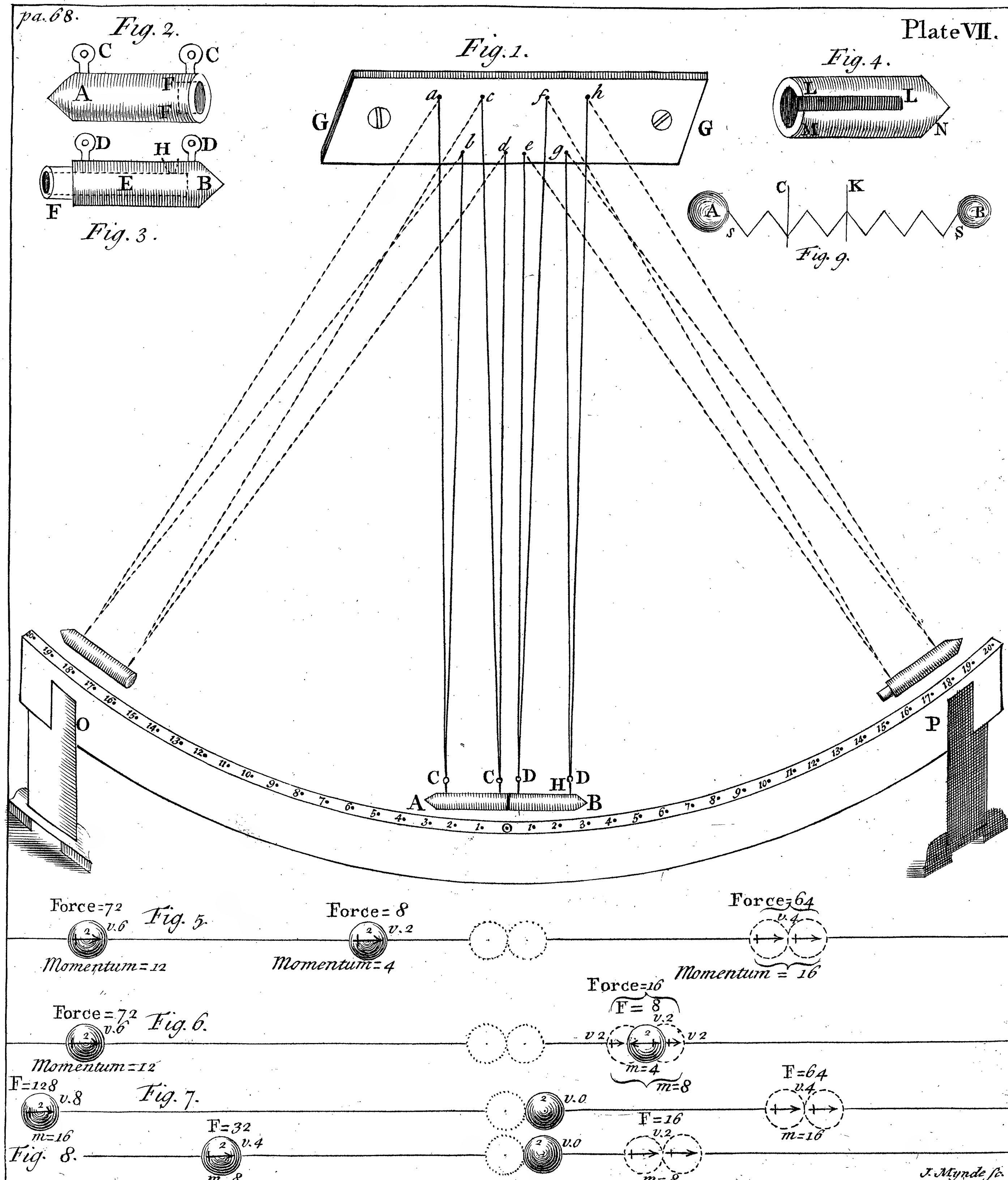
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Plate VII.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 9.
Force=72
v.6
Momentum=12
Fig. 5.
Force= 8
v.2
Momentum=4
Force=64
v.4
Momentum = 16
Force=16
F = 8
v.2
v 2
v 2
m=4
m=8
Force=72
v.6
Fig. 6.
Momentum=12
F=128
v.8
Fig. 7.
m=16
v.0
F=64
v.4
m=16
F=32
v.4
Fig. 8.
m 8
v.0
F=16
v.2
m=8
J. Mynde sc.

has been universally receiv'd, and is one of the Hypotheses laid down by the learned Author of *the Discourse on Motion*, who speaks thus on this Subject: "La Force du Choc, ou de l'Action des Corps, les uns sur les autres depend "uniquement de leurs Vitesses respectives." From thence he infers, it must be the same in a Space that is at rest, as in a Space moved with an uniform Motion in any Direction *. It is from this Principle, and not from his Estimation of the Forces of Bodies, that he deduces his Rules for determining the direct Collisions of two Bodies in the next Chapter of his Discourse; and it is for that Reason, that they agree with the Rules we deduce from our Principle. He does not bring in the Measure of the Forces till afterwards. Now if the Force of the Stroke and Action of Bodies is the same in a Space at rest as in a Space mov'd uniformly, how can the same Action produce on the same Body a Force as 3 in the one Case, and as 1 only in the other †? Annotat. Lect. VI.

69. In general, if their Estimation of the Forces is just, the same Effort or Action will produce on the same Body a different Force in a Space, when the Velocity with which this Space moves is different. If the Velocity of the Space is m, the Velocity imprinted on the Body in the Space is n; the Velocity of the Body in absolute Space will be $m + n$, and its Force $m m + 2 m n + n n$, according to their Measure of Force.

The Force added to the Body by the Action of the Springs upon it, is the Excess of this above $m m$, the Force with which the Body moves when it is at rest in the Space; this Excess is $2 m n + n n$, which Quantity not only depends on n, the Velocity impress'd on the Body in the Space, but also on m, the Velocity with which the Space itself moves; and varies when n is the same, if m vary ‖.

70. When I first proposed this Argument ** against the new Doctrine, I supposed a Person aboard a Ship, and another on the Shore making equal Efforts, and throwing equal Bodies A and B in the Direction of the Motion of the Ship. I supposed that he on the Shore impress'd on the Body B a Velocity, as 8, and inferr'd, That the Body must move in the Ship with an equal Velocity as 8, and in the Air (if the Ship be supposed to move with a Velocity as 2) with a Velocity as $8 + 2 = 10$. The Force of the Body A before it receiv'd this new Impulse was as 4, (its Velocity in the Ship being as 2) according to the new Doctrine, and since it ought to receive the same Augmentation from the same Effort as B, which receives a Force as 64, the Square of 8, the whole Force of A in the Air ought to be $64 + 4 = 68$. But since its Velocity in the Air is 10, its Force ought to be 100, and not 64; from which I

* It will appear hereafter, that this is not universally true, &c.

† In the System of Bodies among themselves; but not when Bodies in the System act on Bodies out of it: in which Case the Velocity of the System itself is to be added to, or substracted from, the particular Velocity of the Body acting, &c.

‖ Yes; because according to the new Opinion, the total Effect (which they call the Measure of the Force) is not proportional to the Sum of the Squares of m, and of n; but to the Square of $m + n$.

** In the Piece that obtain'd the Prize in the Royal Academy of Sciences in 1724.

Annotat. Lect. VI.

I concluded, that this Meaſure of Force could not be juſt. I ſuppoſed afterwards, that theſe Bodies ſtruck invincible Obſtacles, one in the Ship, and the other on the Shore; and becauſe they ought to loſe equal Quantities of Force by theſe Strokes, and the Body B loſing the whole Velocity as 8, ought to loſe a Force as 64; the Body A loſing the ſame Force, ought to be reduced from a Force as 100, (its Velocity in the Air being 10) to a Force equal to 100 — 64 = 36; whereas its Velocity is reduc'd to 2, and its Force cannot be more than 4, which again ſhews this Meaſure of Force cannot be juſt *. This is the ſame Argument I have given here; only, inſtead of a Perſon throwing the Bodies, I ſubſtitute Springs; becauſe an ingenious Author endeavours to raiſe ſome Difficulties from the Re-action of the Perſon in the Ship, which may in ſome degree affect its Motion. It might be eaſy to ſhew this cannot affect the Argument; but, to avoid needleſs Diſputes on this Subject, we have ſubſtituted the Springs, which do not appear liable to that Objection, eſpecially as we conſider them in the following Article.

Plate 8. Fig. 1.

71. For this Argument will have a new Force, by ſuppoſing the Springs plac'd in the Space acting on the equal Bodies A and B, and moving them with equal Forces in oppoſite Directions. Reſuming the Suppoſitions in the 68th *Art.* the Springs being ſuppoſed to add to A a Velocity as 1, muſt ſubduct from B an equal Velocity; and ſince the Velocity of the Space, and all contained in it was 1, the Body B will be abſolutely at reſt, after the Springs have ſubducted from it its Velocity and Force, as 1. Now the ſame Springs by the ſame Action add to A a Force as 3, and ſubduct from B a Force that is only as one. Yet it is plain the Springs act equally on theſe equal Bodies. Here then it is evident that this new Doctrine is inconſiſtent with the plaineſt and cleareſt Ideas we can frame of Force, Action and Re-action. Theſe Reaſonings are ſimple and eaſy, and moſt fit for examining the fundamental Queſtion †.

72. In general, reſuming the Suppoſitions of the 69th *Art.* the Springs add to A a Velocity as n, and ſubduct from B an equal Velocity. Therefore the total Velocity of A muſt be $m + n$, that which they leave to B muſt be $m - n$, the Square of theſe are $m\,m + 2\,m\,n + n\,n$, and $m\,m - 2\,m\,n + n\,n$; the Force therefore added to A by the Action of the Springs is $2\,m\,n + n\,n$, that ſubducted from B is $2\,m\,n - n\,n$; ſo that they add to A a Quantity of Force which exceeds that which they ſubduct from B by $2\,n\,n$, if the new Doctrine could be true ‖. But as it is impoſſible they can act otherwiſe in this Caſe than to produce equal Effects on both, this Doctrine muſt be rejected.

73.

* The Effect is as the Square of the total Velocity, however produc'd. See the laſt Note.

† No; ſince all that the Springs do, is to encreaſe the Velocity from 1 to 2; and bring the Velocity of the other to nothing.

‖ There is no Paralogiſm in this, if we conſider that thoſe of the new Opinion meaſure the Force by the Square of the Velocity, however acquir'd; and indeed allow that what one gains in Velocity the other loſes it; but not till after the Springs have done acting.

73. It does not add to the Argument, but may illustrate the Force of it, to consider, that according to this new Doctrine near 2000 times more Force is added to the Motion of a Body projected directly East at the Equator, with a Velocity that makes it describe a Mile in an Hour, than would be added to it if the Earth was at rest; because every Body, by the Motion of the Earth, describes there near 1000 Miles in an Hour, and by supposing the Earth to move still more swiftly, a greater Force will be added in any Proportion, if this Doctrine is admitted. Annotat. Lect. VI.

74. Before we leave this Argument we have this to add, that a Body perfectly elastick, A, moving with a Velocity as 101, and overtaking another equal Body B perfectly elastick, moving with a Velocity as 100, those after the Stroke exchange Velocities, and the Body B receives an Augmentation of Velocity as 1, but an Augmentation of Force according to the new Doctrine equal to $101 \times 101 - 100 = 10201 - 10000 = 201$; whereas if the same Body A, moving with a Velocity as 1, strike B quiescent, they will exchange Velocity, and B will receive an Augmentation of Force as 1 only. Now in these two Cases the respective Velocity is the same; that is, the Velocities with which they approach to each other, which in both Cases is as 1, and by the Passage we cited from the fore-named Discourse, the Actions depend on the respective Velocities *, and here ought to be the same; whereas the one produces an Augmentation of Force equal to 201, the other a Force as 1 only; the one subducts from A a Force as 201, and the other subducts a Force as one †. Plate 8. Fig. 2.

In general, according to their Opinion, the same Action in the same Bodies must produce different Effects, when that Velocity which is common to both is different, and an Action that arises from an exceeding small respective Velocity may produce a Force of any Quantity, tho' never so great. Plate 8. Fig. 3.

75. We now proceed to a new Source of Arguments, that arises from the Composition and Resolution of Motion, which we shall consider the more fully, because it is from the same Source, that a very learned Mathematician has drawn Arguments for the new Doctrine, capable, as he thinks, to convince those that are most obstinately attached to the common Opinion. Let us resume the Suppositions of that *Art.* where we demonstrated the Composition of Motion. Only first suppose the Angle B A D to be an acute Angle, and the Force A C will be compounded of two Forces A B and A D, whose Sum, according to their Measure of Forces, is less than the Force A C, which they compound. For the Velocities being as the Lines A C, A B and A D, and the Square of A C exceeding the Sum of the Squares of A D and D C, or of A D and A B, by *Prop.* 11. *Book* 2. of *Euclid*, the two Forces in the Directions A D and A B must, according to the new Doctrine, compound a Force A C greater than their Sum. Now this appears against the clearest Plate 8. Fig. 4.

* This is not true in all Cases.

† The Change in the Bodies as to Velocity, is the same in both Cases, and so far proportionable to the respective Velocities; but the Measures of the *Forces*, according to the new Opinion, being (as has been said) as the Square of the absolute Velocities; no wonder there appears so great a Difference.

Annotat. Lect. VI. cleareſt Evidence, and as abſurd in Mechanicks as that two Quantities collected together ſhould exceed their Sum in Geometry *.

76. It is ſo far from true, that the Forces † A B and A D can compoſe a Force greater than their Sum, that it muſt on the contrary be always leſs; for the Force A B and A D muſt always produce a leſs Effect in any other Direction, as A C, than in their own reſpective Directions. Let D M and B N be perpendicular on A C, the Force A D, eſtimated on the Direction A C, is found to give A M for its Meaſure; and A B, eſtimated on the Direction A C, is meaſur'd by A N, as we ſhew'd above; and that theſe Quantities are leſs than A D and A B, is obvious. It will appear ſtill more plain that A B and A D muſt compoſe in the Direction A C a Force leſs than their Sum, if you compleat the Parallelograms A M D K, and A N B L. For the Force A D may be conſider'd as compoſed of the Forces A M and A K, and the Force A B, as compounded of the Forces A N and A L, whereof the Parts A K and A L are oppoſite and equal, and deſtroy each other; ſo that the whole Forces A D and A B are not accumulated in the Direction A C, but only their Parts A M and A N, which together are equal to A C, becauſe A M = C N, the Triangles A D M and B C N being ſimilar and equal. Since therefore the Forces in the Directions A B and A D muſt compoſe a Force in the Direction A C leſs than their Sum, and yet the Squares of A B and A D, taken together, exceed the Square of A C, it follows, that theſe Forces are not to be meaſured by the Squares of thoſe Lines, according to the new Doctrine.

77. This will be ſtill more evident, by conſidering that it is allow'd on all ſides, that two Preſſures, or infinitely ſmall Forces, (ſuch as ariſe from the Weight of heavy Bodies acting in the Directions A B and A D ‡, proportional to theſe Lines A B and A D) compound a Preſſure in the Direction A C, that is leſs than their Sum, or in the ſame Proportion as A C is leſs than the Sum of A B and A D: ſo that a Preſſure at A is proportional to A C, and acting in the Direction C A, is able to ſuſtain them, and take away all their Effect. This is true, for the ſame Reaſon for which we ſhew'd that the two Forces in theſe Directions A B and A D compounded a Force in the Direction A C leſs than their Sum, but equal to the Sum of A N and A M, the Meaſures of theſe Forces in the Direction A C. As Forces are compounded and reſolved in the ſame manner as Preſſures, which are only very ſmall Forces,

‡ Plate 8. Fig. 5.

* To ſhew the true State of the Caſe; if by Forces the Profeſſor meant no more than *Momenta*, (according to the old Opinion) then the *Momenta* expreſs'd reſpectively by A D and A B, and acting in thoſe Directions, will compound a *Momentum* repreſented by, and in the Direction of, A C, which is leſs than the Sum of A D and A B: and yet no Abſurdity follows from the new Opinion, which (by meaſuring *Forces*, not by *Momenta*, but by the Square of the Velocities) concludes, that on account of the Angle A B being acute, the Square of A C (which is the Force compounded) is greater than the Squares of A B and A D, the Sum of what they call the compounding Forces.

† Here is to be obſerved, that by the word *Forces* are only meant *Momenta*; and therefore what follows does not affect the new Opinion; and yet confirms the old, according to the Definition given of Force in thoſe that have defended it.

Forces, and as Forces are produced by Preſſures ſumm'd up or accumulated together, ſo it is evident the Reaſonings about them in this matter ought to be the ſame*. Suppoſe that the elaſtick Body A receives its Force in the Direction A B, from the equal elaſtick Body H, and its Force in the Direction A D from the equal elaſtick Body G at the ſame time. According to the Patrons of the new Doctrine, the Forces are communicated to A by infinitely ſmall Degrees, or by an uninterrupted Succeſſion of Preſſures, and the whole Force † communicated to A is the Sum of the Effects of theſe Preſſures. Now in every Inſtant the Preſſure, or infinitely ſmall Force imprinted on A, is leſs than the Sum of the Preſſures exerted in that Inſtant by H and G, in proportion as A C is leſs than A B + A D, as is allow'd on all ſides. Therefore the Sum of all the Preſſures, or the Force imprinted on A, muſt be leſs than the Sum of all the Preſſures, or the Sum of the Forces exerted by H and G in the ſame Proportion of A C to A B + A D; that is, the Forces of A H and G muſt be as the Lines A C, A B and A D, and not as their Squares. It is not poſſible to conceive that while the Force in A ariſes from the Accumulation of the Preſſures, or infinitely ſmall Forces which it receives every Moment from the Actions of H and G, and each of theſe Preſſures, or infinitely ſmall Preſſures, is leſs than the Sum of the Actions of H and G that produce them; yet the whole Force of A ſhould nevertheleſs exceed the Sum of the whole Actions or Forces of H and G. I ſpeak here of infinitely ſmall Forces, to comply as much as poſſible with the Stile of the Favourers of this new Opinion.

Annotat. Lect. VI.

Plate 8. Fig. 5.

78. As two Preſſures, Weights, or infinitely ſmall Forces in the Directions A B, A D, compound a Preſſure or Effort in the Direction A C leſs than their Sum, (becauſe ſome Parts of theſe Preſſures are oppoſite, and deſtroy each other) ſo this muſt hold while the elaſtick Bodies H and G are acting on A. In every Inſtant a Part of their Effect is deſtroyed in this Oppoſition, while the elaſtick Parts yield and reſtore themſelves again from the Beginning of the Action to its Conſummation. The effect therefore produced upon A, muſt be leſs on this account, than if there was no ſuch Oppoſition; that is, the whole ‖ Force communicated to A, muſt be leſs than the Sum of the Forces H and G. There can be few things ſaid concerning Forces and Preſſures, that can be more plain and evident than this ſeems to be. It ſeems very clear that a Force is equal to the Sum of the Preſſures, or infinitely ſmall Forces that are wholly employ'd in producing it, and that produce no other Effect but it; only the Parts of Preſſure of H and G, that are as A N and M N, are thoſe which are totally employ'd in generating the Force of A, and have no other Effect but that Force only; while the Parts that are as B N and D M,

* Tho' *we* mean the ſame thing by Preſſures and Forces, according to the old Opinion, *they* do not.—See *s' Graveſande* in ſeveral Places.

† This ought to be call'd the whole *Momentum*; and it will be allow'd by thoſe of the new Opinion.

‖ This will be all right if the word *Momentum* be ſubſtituted inſtead of the word *Force*; but this will bring no Abſurdity on the new Opinion, &c.

Annotat. Lect. VI.

Plate 8. Fig. 5.

D M, or as A P and A Q, equal and oppoſite deſtroy each other's Effect, and contribute no part towards the Force of A. The Force therefore imprinted on A in the Direction A C, is the ſame as if Preſſures equivalent to the Parts of the Preſſures of H and G, that are as A M and A N, were acting upon it only; and this Force muſt be to the whole Force of H and G, as A N + A M (= A C) that expreſſes the Sum of the Preſſures, is to A B or A D, and not as the Squares of thoſe Lines.

79. The firſt Action of H and G in the Direction A B and A D on the Body A, when they begin to compreſs its Parts, and puſh it in the Line A C, are Preſſures proportional to A B and A D, and generate in A an infinitely little Force, or Preſſure, proportional to the Diagonal A C, as the Authors on the other ſide of the Queſtion muſt themſelves allow. The following Actions obſerve the ſame Proportion. How can the Force of A therefore become ever ſuperior, or even equal to the Sum of the Forces which H and G loſe in acting upon A, ſince A C is always leſs than the Sum of A B and A D *. We have ſuppoſed the Bodies elaſtic, and the Action to proceed by infinitely ſmall Degrees in conformity to their favourite Principle, or Law of *Continuity*. But if you ſuppoſe the Bodies perfectly hard, and the Action to be begun and conſummated in a Moment, it will be evident, that in that Caſe the Actions can be eſtimated no other way, than as Preſſures in the ſame Directions are eſtimated by all Authors. The oppoſite Parts of the Forces A B and A D, which are A P, A Q, deſtroy each other; and the Parts that remain, A N and A M, produce a Force equal to their Sum A C †.

80. According to the new Opinion, when the Angle B A D is a right Angle, the Forces as A B and A D generate in A in the Direction A C, a Force equal to their Sum. Suppoſe that Angle to become acute, and the ſame Forces generate in A a Force greater than their Sum, and when the Angle B A D is infinitely acute, the ſame Forces generate a Force in A that exceeds their Sum as much as the Square of $AB + AD$ exceeds $AB^2 + AD^2$; ſo that if $AB = AD$, they will in that Caſe generate in A a Force double of their Sum, for then the Square of $AB + AD$ will be equal to the Square of $2 AB$; that is, to $4 AB^2$; tho' the Forces that produce this, taken together, are equal to $2 AB^2$ only, according to their own Computation. How can they pretend therefore to build on the Principle, that Effects are proportional to their Cauſes, when a Cauſe in this Caſe produces an Effect of the ſame kind double of itſelf ‖?

81.

* This is allow'd to be true of the *Momenta*.

† Here again ſubſtitute *Momentum* to the Word *Force*, and all will be right.

‖ Becauſe a double *Momentum* may produce a quadruple Effect, according to the new Opinion, if the Velocity is double.

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81. It appears, that when two Forces acting in different Directions compound a third Force in a new Direction, this third Force cannot be equal to the first two taken together, but to those Parts of them only as are their Measure in that third Direction, the other Parts being opposite and equal, and destroying each other. This is easily understood to follow from the Principles of Motion, which require only that the same Quantity of Motion or Force * should be preserved in the same Direction; and from this it follows, that when a Force is resolved into two that compound it in their respective Directions, their Sum must exceed the first Force: As this is objected to the common Opinion, we shall endeavour to shew how it necessarily flows from the Principle of Motion.

82. Suppose the three Bodies A, B and C, are equal to each other, and perfectly elastick. Suppose that A and B move in the Directions A C, B C, perpendicular to each other, with equal Velocities, which we represent by the equal Lines A C and B C, and let A and B at the same time strike C quiescent directly; then shall A and B stop, and C move with a Motion compounded of the two, which it has receiv'd from A and B in the Direction F C D, which bisects the Angle A C B. Take C K and C L equal to A C and B C, and compleat the Square C K D L, and the Body C shall describe the Diagonal C D in the same time that A and B would have described the Sides of the Square. In the first place, the Force with which the Body C moves must be less than the Sum of the † Forces A and B, because these Forces, which are as A C and B C, may be resolved each into two, *viz.* the first into the Forces A F and A M, the second into the Forces B F and B N, whereof these in the Direction A F and B F destroy each other, and have no Effect on the Body C; the other two, which are each as F C, are accumulated in C, and constitute the Motion as C D = 2 F C, which must be less than A C and B C. Plate 8. Fig. 6.

"There is another way whereby the Favourers of the new Doctrine "think to prove their Assertion, by considering the Resistance of Springs in "the following manner. In order to prove that the Body D, (acted upon by "two Forces, whose Quantities and Directions are represented by the Lines "D E and D F) going in the Diagonal Line D C, has a Force as the Square "of its Velocity, (D C?) they alledge that a Spring fix'd at A will be bent "by the Body C coming from D with the Force E C, and afterwards the "Body going to an equal Spring at B, that Spring will be bent with a Force "C B = F A. Consequently that the Resistance of the two Springs being "equal to the Actions by which they are bent, (*viz.* E A × A B = D F × "D E) are the Measure of the Force of the Body moving in the Diagonal "D C, that is, as the Square of its Velocity. Plate 8. Fig. 7.

"Now that the Sum of the Resistances of the Springs are not the Measure "of the Force of the Body bending them, will appear, if we consider that their "Resistance may exceed

* These are not synonymous, &c.

† Provided no more is meant by *Force* than *Momentum*, &c.

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N. B. *A Leaf of Mr. Professor* MAC-LAURIN'*s Manuscript being lost, I have here supplied what I supposed was wanting.*

may exceed the whole Force of C, because the one acts against the Body obliquely; and, besides diminishing the Force of the Body, changes its Direction. It is certain that the Spring A acts at disadvantage against the Motion of the Body, while the Spring at B acts directly against it, and employs its whole Resistance in destroying its Motion. The Spring A has its whole Effect in that Direction in which it resists, (*viz.* in the Direction C E, or F D) and has an Effect in that Direction equal to the Effect of the Spring B in the Direction B A, in which that Spring resists. But the Spring A has not so great an Effect in the Direction C D; for that is not the Direction in which it acts, but oblique to it. If the Spring A acted with the same Advantage as B, they would together produce a greater Effect than in the Situation they have in the Figure; and therefore the greatest Resistances which they are able to exert taken together, must exceed the Force of the Body C. Thus it appears that this Argument, instead of overthrowing our Doctrine, confirms it, and that they who advanc'd it suppos'd these Forces to be equal; which, according to the known Principles of Mechanicks, are unequal. As in other Instances they neglect the Consideration of Time in reasoning about the Forces of Bodies; so here we find that they have no regard to the Directions of Forces in estimating their Effects. If it is asked what becomes of the Excess of the Force of the Spring A, above what is subducted from the Force of C; it may be answer'd, that it is not without its Effect: for the Direction of the Body is chang'd from the Line D A into the Line A B, and no other Principle, either in Metaphysicks or Mechanicks, teaches us that this Effect is to be neglected in comparing the Cause and Effects together on this Subject. On the contrary, there are many Instances where a Force is employ'd in producing a Change in the Direction of Motion, only without either accelerating or retarding it.

THE Force that is sufficient to carry a Body upwards in a Perpendicular to the Horizon, to a double Distance from the Center of the Earth, is equal to that which imprinted in an horizontal Direction would carry it in a Circle about the Earth for ever: and yet the first would overcome the Resistance arising from the Gravity of the Body for a certain Time only; whereas the other would overcome that Resistance for ever, without any Diminution of Motion. In the first Case, the Gravity of the Body would act directly against its Force; in the second, it would act in a Line perpendicular to the Direction of the Motion of the Body. In the first Case, the Action of Gravity is entirely employ'd in consuming the Force of the Body; in the other, in changing its Direction only. Thus far Mr. *Mac-Laurin.*

WHAT has been written in defence of the new Opinion, in Opposition to the Favourers of the old, where the Author has carried the Matter farther than was suitable to the Nature of his Subject, is a Dissertation by *Frider. Wilhelmus Stubner*, who thought that *Time* might be taken in the Consideration of the Measure of Force, according to the new Opinion: but there the whole Effect should be consider'd, without any regard to *Time*. Mr. *Charles*

L'Abelye,

L'Abelye, Engineer to the Commiſſioners for building of *Weſtminſter* Bridge, has very well diſtinguiſhed upon that Subject; and ſhewn very plainly, wherein Mr. *Fred. Wilhel. Stubner* has been miſtaken, in a Letter ſent to me in the Year 1735: which I take the liberty to publiſh here; becauſe I would omit nothing that may ſerve to clear up this Matter fully, that there may be no more Diſputes about it. Annotat. Lect. VI.

To the Reverend Dr. J. T. Desaguliers, LL. D. F. R. S.

April the 15th, 1735.

Reverend S IR,

I Have drawn up, according to your Deſire, an Account of Mr. *Stubner*'s pretended Demonſtration of the new Opinion relating to the Forces of Bodies in Motion; and I have added, at the End, ſome Remarks, wherein I have laid open the Paralogiſm. I could have wiſh'd it had been poſſible to have reduced it into a leſs Compaſs, which I found difficult to do without running the riſque of not being clear, or leaving out the ſeveral Quotations, to which the Reader muſt be referr'd, not only out of our Author's Diſſertation, but alſo out of Mr. *Wolfius*'s *Coſmologia*. Pleaſe to alter, and correct it, where you'll find it neceſſary; and diſpoſe of it, as you ſhall think moſt proper. Pleaſe to take notice that our Author having made uſe of the *German* Algebraical Notation, and that Notation being leſs known in *England* than the other, I have taken the liberty to alter it accordingly in the Quotations.

An Account of a Latin *Diſſertation, intitled*

FRIDER. VILELMI STÜBNER, A. M. ORD. PHILOS. LIPS. ADSSESS. REGIAE SOCIETATI SCIENTIARVM BORVSSICAE, QVAE BEROLINI FLORET ADSCRIPTI. DEMONSTRATIO, VERAE MENSVRAE VIRIVM MOTRICIVM VIVARVM, E LEGITIMIS PRINCIPIIS DYNAMICES LVCVLENTIVS EXPOSITIS, PETITA.

That is,

The Demonſtration of the true Meaſure of the Forces of Bodies in motion, deduced from the received Principles of the Dynamicks, and thoſe Principles more clearly explain'd; by Fred. William Stübner, A. M. *&c. &c. &c.*

To which are ſubjoin'd ſome Remarks, wherein is ſhewn the Paralogiſm of this pretended Demonſtration. This Diſſertation containing 22 Pages in Quarto, ſmall Letter, beſides the Title-Page, and a Preface to the Reader, containing two Pages, was publiſhed about the beginning of the Year 1734, the Date at the End of the Preface being *Leipſick* x. *Decemb.* 1733. I ſhall

Annotat. Lect. VI. ſhall tranſlate from the Author, not only all the material Part, but alſo whatever may ſerve to explain, or give a full Idea of the Author's Reaſonings; and leſt it ſhould be thought I might have given, any where, a Meaning to the *Latin* of this Author different from the true one, I have placed the Words of the Text, and of the Original Quotations, at the bottom of the Page, that the Reader may have it in his power to compare them.——Our Author expreſſes himſelf in the Preface to the Reader as follows:

" *I have endeavour'd (as much as I could) to follow, with the utmoſt " rigour, the Method of the Mathematicians in my Reaſonings: being of " opinion it would be the moſt acceptable; ſince the Diſpute about Forces " is a Subject intirely Mathematical.*"

And a little farther he adds,

" *As the Reaſoning I have made uſe of to eſtabliſh the true Meaſure of " Forces, ſeems the moſt natural that could be offered, and as the firſt " Chapter of this Diſſertation (wherein the Principles of the Dynamicks, " or Forces in general are delivered) contains nothing but Truths agreed " on by all ſides, I have premiſed it in this place, partly that the Read- " er may not be obliged to ſeek for the Proofs any where elſe, ſince he " can have them ready at his hands, and partly to uſe my Endeavours " to illuſtrate, or prove more evidently than what is generally done, thoſe " Dynamick Principles, tho' they can't be made more certain than they " are. For which Reaſon, I hope this Diſſertation will determine, and " end the Controverſy about the Meaſure of Forces of Bodies in Motion, " and bring to our Opinion thoſe that thought otherwiſe.*"

The Diſſertation itſelf is divided into two Chapters, in the firſt our Author delivers what thoſe Gentlemen, which eſpouſed Mr. *Leibnitz*'s Opinion, as to the Meaſure of Forces, call the Principles of the Dynamicks, or of Forces in general. I ſhall ſhew hereafter that the Forces of

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Quantum valui, Mathematicam Methodum, ejuſque ſummum Rigorem, adſequi contendi, ratus, non vitio id mihi verſum iri, quum præſertim de propoſitione Mathematica omnis controverſia ſit.

Quoniam hæc Argumentatio, qua uſus ſum, pro adſtruenda vera menſura virium, omnium maximè naturalis videtur, totumque primum tractationis caput, de principiis Dynamices legitimis, conſtet veritatibus quibus omnes adſentiuntur, & quæ ſolum ideo a me repetitæ ſunt, ut partim lectoribus præſto eſſent, nec aliundè petenda forent convictionis ſubſidia, partim, quum certiores illæ reddi nequeant, evidentiores aliquo modo, mea qualicumque opera, fierent, quam vulgo proponuntur confido fore, ut hac ſcriptione, omnis controverſia de vi metienda motrici finiatur, ſecuſque ſentientes, ad noſtram pertrahantur ſententiam.

of Bodies already in motion, (which is the Subject in dispute) are not subjected to the same Rules which are delivered here, for the Measure of Forces in general; and that the Theorems contain'd in the first Chapter of this Dissertation are true, only of the Forces which put Bodies in Motion, or change the Motion they had before, either as to Intensity, or Direction, or both. Annotat. Lect. VI.

OUR Author says, in the beginning of the first Chapter, that he supposes his Readers have a clear Notion of what they call *Vires Motrices*, or the Forces of Bodies in motion, and that those who are not as yet sufficiently acquainted with those notions, must consult the famous *Chr. Wolfius*'s *Cosmologia*. As this Book of Professor *Wolfius* is not very common in *England*, I have translated out of it, in this place, what our Author mentions, and whatever else may serve to shew the real Notions of that learned Professor and his Followers.

" §. 129. *All Bodies resist to Motion.*

" §. 130. *The Principle of Resistance to Motion in Bodies, is called* " *the* Vis Inertiæ, *or the passive Force.*

" §. 132. *A Body resists to every change by its* Vis Inertiæ.

" §. 135. *Since a Body acts, to put another quiescent Body in mo-* " *tion, or to alter the Motion of a Body already in Motion, either as* " *to its Direction, or its Celerity, or as to both*; a Body being once in " Motion, is endowed with a Force to act.

" §. 137. *This Active Force is called the Moving Force* (Vis Mo- " trix) *because it is inseparable from local Motion.*

" §. 149. *This active Force* (Vis Motrix) *consists in a continual En-* " *deavour to change Place.*

" §. 170. *All Matter is in a continual Motion.*

" §. 356. *A Force is said to be dead* (Vis Mortua) *which consists in nothing*

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§. 129. Omne Corpus resistit motui.

§. 130. Principium Resistentiæ motus in corporibus dicitur *Vis Inertiæ*, sive vis passiva.

§. 134. Corpus vi inertiæ omni mutationi resistit.

§. 135. Quoniam corpus, vel quiescens ad motum concitans, vel in motu constituti motum immutans, sive quoad directionem, vel ad celeritatem solam, sive quoad utrûmque, agit, *corpus in motu constitutum vi agendi præditum est*.

§. 137. Vis illa corporum activa dicitur Vis Motrix, quia semper motui locali adheret.

§. 149. Vis motrix consistit in continuo conatu mutandi locum.

§. 170. Omnis materia in continuo motu est.

§. 356. Vis dicitur Mortua quæ in solo conatu ad motum subsistit—

ut

Annotat. Lect. VI. " *nothing but the Endeavour, or the Tendency to Motion. Such is* " *Gravity as long as a heavy Body, hung by a Thread endeavours to* " *descend, but cannot actually descend. Such is also the Force of a bent* " *Spring, whilst it endeavours to restore it self to its natural State, but* " *cannot restore it self on account of an Obstacle,* &c.

" §. 357. *A Force is said to be alive, or* quick, (vis Viva) *which always* " *accompanies actual Motion, and tends to produce a local Motion. There* " *is such a Force in a Body, falling by Gravity, when it has already* " *acquired some Degrees of Velocity, and such a Force is also found in a* " *Spring, whilst it does actually unbend itself; nor is the Force of a Bul-* " *let, shot by the Force of Gun-powder out of a Cannon, different from* " *this. Mr.* Leibnitz *was the first, who begun to enquire into the Dif-* " *ference (between these two sorts of Forces* Vis viva & Vis mortua, *which* " *had been neglected till then, by the Mathematicians as well as the Phi-* " *losophers) in the* Acta Eruditorum A. D. 1695. page 149.

" §. 471. *A hurtful Effect* (effectus nocuus) *is that which destroys* " *the Force, by which it is produced; but a harmless Effect* (effectus in- " nocuus) *is that which does not destroy the moving Force, but leaves it* " *unalter'd. For Example, in an uniform Motion, the Effect of the* " Vis motrix *is to carry the moving Body thro' Space. Now if the Mo-* " *tion is perform'd in a Medium that does not resist, the Effect is harm-* " *less* (innocuus): *If the Motion is perform'd in a resisting Medium, it* " *is certain that the Velocity, and consequently the Force decreases con-* " *tinually, and therefore that Effect is hurtful* (nocuus.)

" §. 473. *The hurtful Effects, are as the Forces which they destroy,*&c. *Hence*

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ut gravitas quamdiu grave ex filo suspensum descendere nititur, tamen actu descendere nequit: etiam talis est vis in Elastro tenso, dum se restituere nititur, ob præsens autem obstaculum restituere nequit, *&c.*

§. 357. Vis viva, quæ cum motu actuali conjuncta est, ad motum localem porro producendum tendit; Vis viva est in gravi cadente ubi jam aliquem gradum celeritatis adquisivit. Talis etiam deprehenditur in Elastro tenso dum actu restituitur, nec alia inest globo, vi pulveris pyrii, ex Tormento exploso; Differentiam Vis vivæ a mortua, cum a Philosophis, tum a Mathematicis, neglectam primus scrutari cepit Leibnitzius in Acta Eruditorum A. D. 1695. pag. 149.

§. 471. Effectus nocuus, est qui vim, qua producitur, absorbet; Effectus vero innocuus, est qui vim motricem non absorbet, sed eam intemeratam relinquit. Ex. gratia, in motu equabili, effectus Vis motricis est translatio mobilis per spatium, enimvero si motus fit in medio non resistente, effectus innocuus est; si movetur in medio resistente, constat celeritatem continuò decrescere, & consequenter vim quoque; effectus ergo nocuus est.

§. 473. Effectus nocui sunt, ut vires quas absorbent, &c. hinc pervulgatum

" *Hence that famous Theorem, which says,* that the Effects must be proportionable to the Forces, or the Causes that produce them, *must be understood only of the hurtful Effects* (effectus nocui,) *because the same cannot be demonstrated of all Effects in general, and the contrary rather may be shewn, as is plain from the very Definition of the harmless Effects* (effectus innocui.) Annotat. Lect. VI.

" §. 474. *Since the Quantity of the hurtful Effects* (effectus nocui) *depends intirely on the Quantity of the Forces which they destroy; in the Estimation of those hurtful Effects* (effectus nocui) *no regard is to be had to the Times.*"

Having now premised *Wolfius*'s Definitions, which our Author supposes his Readers to adopt as he does himself, I shall proceed to give the Substance of our Author's Dissertation.—He proceeds next to deliver his Notation, that is, to expound the Symbols he employs, which are as follows.

If two Forces produce their Effects by acting, or continuing to act during certain Times, and those Forces be represented by V and v, the Effect of the Force V produced in the Time T, he calls E, and the Effect of the Force v produced in the Time t he calls e.

I shall shew hereafter, that notwithstanding our Author applies this Notation, and what he deduces from it, to all Forces in general; it ought only to be applied to the Forces by which Bodies are put into motion, or have their motions altered; and that it is of such Forces only, which are greater or less, or rather, which produce a greater or a less Effect, according to the times during which they act, that it may be affirmed, what our Author delivers in the four following Propositions, in which is summed up all the Doctrine contained in the 15 Pages of his first Chapter.

" §. 34. *The Effects that are produced by the same or equal Forces, are in the Ratio of the Times during which they are produced*; so that if $V = v$, then $T : t :: E : e$.

" §.

tum istud Theorema, de effectibus causæ seu viribus causæ suæ proportionalibus, non intelligendum nisi de effectibus nocuis, neque enim in genere de effectibus id demonstrari potest, quin potius contrarium ostendi potest; imo ex ipsa definitione effectus innocui per se patet.

§. 474. Quoniam quantitas effectuum nocuorum pendet a quantitate virium quas absorbent, in effectibus nocuis estimandis, non habenda est ratio Temporum.

§. 34. Effectus ab æqualibus viribus, vel eadem vi præstiti rationem temporum, in quibus producuntur ipsi sequuntur, ergo si erit $V = v$ erit etiam $T : t :: E : e$.

Annotat. Lect. VI.

" §. 35. *If two Forces produce unequal Effects, in different Times, " those Forces are in a Ratio compounded of the direct Ratio of those " Effects and the reciprocal Ratio of the Times*; that is, those Forces " will be as the Effects they produce divided by the Times during which " they act. So that $V : v :: Et : eT$, or $V : v :: \frac{E}{T} : \frac{e}{t}$, for if the " Force v in the time t, produces its Effect e, the Force V in the same time " t will produce an Effect $= \frac{eV}{v}$, since in equal times the Effects are " as the Forces: Moreover, if the Force V in the time t produces an " Effect $= \frac{eV}{v}$, that same Force V, in the time T, will produce " an Effect $= \frac{TeV}{tv}$ (by the last Parag. 34.) but the Effect of the Force " V, in the Time T, is $= E$; therefore $\frac{TeV}{tv} = E$, consequently TeV " $= tvE$, and therefore $V : v :: Et : eT :: \frac{eT}{t} :: \frac{E}{T} : \frac{e}{t}$.

" §. 36. *Therefore the Effects of Forces* in general *are in a Ratio " compounded of the direct Ratio's of the Forces, and of the Times*; that " is, the Effects of Forces, are as the Forces multiplied by the Time " of their Action, because by the last we have $TeV = tEv$, it follows " that $E : e :: TV : tv$.

" §. 37. Moreover, since $TeV = tEv$, it follows also that $T : t$ " $:: Ev : eV :: \frac{E}{V} : \frac{e}{v}$; that is, *the Times are in a Ratio compounded of*

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§. 35. Si vires duæ effectus inæquales, inæqualibus in temporibus produxerint; sunt illæ in ratione composita, ex effectuum directa, & temporum inversa rationibus, dico fore $V : v :: Et : eT :: \frac{E}{T} : \frac{e}{t}$. Nempè si vis v producet, in tempore t, effectum e, producet vis V, in eodem tempore t, effectum $\frac{eV}{t}$, si porro vis V in tempore t, producet effectum $\frac{eV}{v}$, vis eadem V, in tempore T producet effectum $\frac{TeV}{tv}$; sed effectus vis V, in tempore $T = E$, ergo $\frac{TeV}{tv} = E$ & $TeV = tvE$, ac denique $V : v :: Et : eT ::$ $E : \frac{eT}{t} :: \frac{E}{T} : \frac{e}{t}$.

§. 36. Sunt adeo effectus *quarumcumque* virium, in Ratione composita, e Rationibus directis virium & temporum, nam cum $TeV = tEv$, erit etiam $E : e :: TV : tv$.

§. 37. Porro quia est $TeV = tEv$, erit $T : t :: Ev : eV :: \frac{E}{V} : \frac{e}{v}$, sunt pro-

" *of the direct Ratio of the Effects, and the inverse Ratio of the Forces*; Annotat.
" or as the Effects divided by the Forces, by which they are produced." Lect. VI.

Our Author endeavours in his second Chapter to apply these Dynamick Principles delivered in the former Chapter, to the Forces that exist in Bodies that are in motion. I shall first relate the Substance of this 2d Chapter, and then make some Remarks upon the whole.

" §. 38. *The* Impetus *of a Body (called by the* English, Momentum, " *and by Sir* Isaac Newton, *Quantitas motus) is the Product of the Mass* " *of the Body multiplied into the Velocity with which it moves*; so $C \times M$ " $= CM$ is the *Impetus* (or *Momentum*) of the Body M, moving on " with the Velocity C, in the same manner $c \times m = cm$ is the Impe- " tus (or Momentum) of another Body *m* moving with the Velocity *c*.

" §. 40. *The Effect of the* Vis Motrix, *or the Force of a Body in Mo-* " *tion, is what that Force produces.*

" §. 41. *The Effect of the Force of a Body in motion* (Vis Motrix) *is* " *the Impetus (Momentum) which the Body in motion has.*

" §. 42. *The Effects of the Forces of Bodies in motion* (Vires Motri- " ces) *are proportional to the Impetus* (or *Momenta*) *of the Bodies in mo-* " *tion, by the Action of those Forces.*

" §. 51. *Those little Intervals of Time, during which the Bodies are* " *found or* remain (hærent) *in every point of the Lines of Direction of* " *their Motions, are reciprocally proportional to the Celerities with* " *which the Bodies move.*

" §. 53, and the following. *The Times which are spent by the* Vires " Motrices, (*or Forces of Bodies in Motion*) *in producing their Effects,* " *are reciprocally proportional to the Celerities, with which those Bo-* " *dies are carried by the Action of those Forces.*

" §.

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proindè tempora in ratione composita, ex effectuum directa, & virium inversa.

§. 38. Impetus est productum Massæ corporis, in celeritatem, qua movetur, sic $C \times M = CM$ est impetus corporis M, moti celeritate C. Sicut $c \times m = cm$ est impetus alius corporis *m* moti celeritate *c*.

§. 40. Effectus Vis Motricis est id quod vis motrix producit.

§. 41. Vis Motricis effectus, est impetus quem corpus motum habet.

§. 42. Effectus virium motricium sunt impetibus proportionales quos corpora ab illis mota habent.

§. 51. Tempuscula per quæ corpora *hærent* in singulis punctis suarum directionis linearum, sunt celeritatibus quibus corpora moventur reciprocè proportionalia.

§. 53, *& seq.* Tempora quæ a viribus motricibus impenduntur producendis effectibus suis sunt reciprocè proportionalia celeritatibus, quibus feruntur corpora illis viribus mota. M 2

Annotat. Lect. VI.

" §. 56. *The Forces of Bodies in motion* (Vires motrices, *which al-* " *ways accompany Motion) are in a Ratio compounded of the direct* " *Ratio's, of the Squares of the Velocities, or Celerities, wherewith the* " *Bodies are carried by those Forces, and of the Matter of those Bodies;* " or in other Words, the Forces of Bodies in motion, are as the Quan- " tities of Matter in the Bodies in motion, multiplied into the Squares " of their respective Celerities. If the Force V moves the Body M with " the Celerity C, let us call the Effect of this Force E, and the Time " that Force employs in producing that Effect T. Let us suppose ano- " ther Force v moving a Body m with the Celerity t, and let us call " the Effect of that Force e, and the time that Force employs to pro- " duce it, t; we shall have $V : v :: E\,t : e\,T$, (by *Parag.* 35.) now " $E : e :: CM : cm$ (by §. 41.) and $t : T :: C : c$ (by §. 53.) There- " fore $E\,t : e\,T :: E\,C : e\,c :: \overline{C}^2 M : \overline{c}^2 m$. *That is, in Words at* " *length; The* Vires Motrices, *or Forces of Bodies in motion are in a* " *Ratio, compounded of the direct Ratio's of the duplicate Ratio of* " *Velocities, or Celerities, and the simple Ratio of the Masses.*"

Having given an Abstract of this Dissertation, I will now endeavour to shew wherein lies the Paralogism of this pretended Demonstration. In order to do this, we must take care, in the first place, to acquire a true Notion of the Terms employed in it, most Disputes arising from different Ideas join'd to the same Expressions, or from different Expressions made use of to signify the same Ideas.

1°. OUR Author, and most of the Followers of *Leibnitz*'s Opinion, (for even in this they are divided) pretend, that when a Body is in Motion, that Motion is to be consider'd only as the Effect of a Force inherent in that Body, whilst in Motion, (different from the *Vis Inertiæ*, which they allow to be inherent in the same Body at rest) which does actually carry the Body from Place to Place, by acting upon it always with the same Intensity, in every Physical Point of the Line which the Body

§. 56. Vires Motrices cum motu actuali conjunctæ sunt in ratione composita, è directis rationibus quadratorum celeritatum, quibus corpora iis viribus feruntur, & massarum horum corporum. Si vis V, moveat corpus M, celeritate C, ejusque Effectus dicatur E, tempusque quo hunc præstat T: atque vis v moveat corpus m, celeritate c, hujusque Effectus dicatur e, tempusque quo hunc præstat t erit (§. 35.) $V : v :: E\,t : e\,T$. Sed est $E : e :: CM : cm$ (§. 41.) & etiam est $t : T :: C : c$ (§. 53.) hinc $E\,t : e\,T :: E\,C : e\,c :: \overline{C}^2 M : \overline{c}^2 m$; vel si verbis agendum sit——Ratio virium motricium, cum motu actuali conjunctarum, componitur e rationibus directis celeritatum duplicata & massarum simplici.

Body describes. This is plain from the 41st Parag. of our Author, and the 471st of *Wolfius*'s *Cosmologia*, quoted above. Now if there is any such Force (called by them *Vis Motrix*) existent in a Body in Motion, different from the *Vis Inertiæ*, that Force must necessarily be created, or generated, at the very Instant a Body is put into Motion, and the *Vis Inertiæ*, which that Body had when at rest, must be annihilated, or destroy'd at that same Instant: or else there would be in the same Body a two-fold Force, *viz.* this (real or pretended) *Vis Motrix*, which carries it on thro' Space, and the *Vis Inertiæ*, by which it endeavours to keep whatever State (of Motion or of Rest) it is in. Whereas if we attentively compare the Definitions of the *Vis Inertiæ* in Sir *Isaac Newton*'s, and in *Wolfius*'s, and others of *Leibnitz*'s Opinion, we may easily see that these two pretended different Forces are in reality but one and the same. Here is Sir *Isaac Newton*'s Definition, as translated by Mr. *A. Motte*, Book 1. Defin. 3. "The *Vis insita, or innate Force of* " *Matter, is a Power of resisting, by which every Body, as much as in it* " *lies, endeavours to persevere in its present State, whether it be of Rest,* " *or of moving uniformly forward in a right Line.* This Force is ever " proportional to that Body whose Force it is, and differs nothing from " the Inactivity of the Mass, but in our manner of conceiving it. A " Body from the Inactivity of Matter is not without difficulty put out of " its State of Rest or Motion; upon which account this *Vis insita* may, " by a most significant Name, be called *Vis Inertiæ*, or Force of Inacti- " vity." Annotat. Lect. VI.

Now from the Parag. 130, quoted above, it appears that they allow that a Body remains at rest, and endeavours against being put into Motion by the *Vis Inertiæ*; and from *Wolfius*'s 132d Parag. quoted above, it appears also that they allow that a Body once in Motion resists to its being alter'd from the State it is in, *viz.* of moving uniformly by its *Vis Inertiæ*, which therefore must be sufficient to maintain that Body in uniform Motion for ever, until a new Cause intervenes; this is the true Idea that we must frame to our Mind of the Force of a Body already in Motion, whether we call it, with Sir *Isaac Newton*, *Vis Inertiæ*, or *Vis Motrix* with the Followers of *Leibnitz*.

2°.

Philosophiæ Naturalis Principia Mathematica, Lib. 1. Def. 3. *Materiæ Vis insita est potentia resistendi, qua corpus unumquodque, quantum in se est, perseverat in statu suo vel quiescendi, vel movendi uniformiter in Directum.*

Hæc semper proportionalis est suo corpori, neque differt quicquam ab Inertia Massæ, nisi in modo concipiendi. Per Inertiam Materiæ, fit ut corpus omne de statu suo vel quiescendi, vel movendi difficulter deturbetur. Unde etiam Vis insita, nomine significantissimo, *Vis Inertiæ* dici possit.

Annotat. Lect. VI.

2°. WHAT our Author calls after *Wolfius*, *Vis viva*, (or *quick Force* conjoin'd with actual Motion) is no more than the *vis insita* of a Body in motion, defined above in Sir *Isaac Newton*; and, to prove it, we need only quote this Author's own Words, (*Parag.* 47.) "When I "shall mention the *Vis viva*, or *quick Force*, which is always joined to "actual Motion, it is evident, from its Definition, (see *Wolfius*'s *Pa-* "*ragr.* 357.) that in considering the *Vis viva* I am treating of those "Forces only, which already exist in the Body when in motion; ab- "stracting consequently from the Communication of the Motion: and "I have regard only to that Force, which is in the Body in motion, "when it moves with its equable, or uniform Celerity; and it is that "Celerity that I mean in what follows."

3°. Now, to avoid disputing about Words, let the Force which is in a Body in motion be called by the Name of *Vis inertiæ*, or *Vis motrix*, our Author makes a wrong use of the Words, and of his Symbols, when he begins his Demonstration (§. 56.) in this manner.——"If the Force "V moves the Body M with a Celerity C, let us call the Effect of that "Force E, and the Time employ'd in producing that Effect T, *&c.*" Because, unless a new Cause intervenes, or a new impress'd Force (*Vis impressa*) interferes, the Force of the Body in motion is the same; (that is, it would remove the same Obstacle, strike the same Blow, or destroy an equal Momentum, acting in a contrary Direction, in any Point of the Line, or Space described in its Motion) so that the Times can have nothing to do in the Computation of the Forces of Bodies already in motion, (*Vires Motrices*, or *Insitæ*) and the Substitution, the Author introduces from a Consideration of the Times being never true, but in one particular Case relating to other sorts of Forces, (*viz.* the *Vires impressæ*) his whole Demonstration must fall to the ground.

4°. MOREOVER, if it was allow'd that the Motion of the Body is owing to the continual Action of a Force, inherent in the Body, (called *Vis Motrix*) it is universally known, (and our Author has demonstrated it very clearly in his §. 26.) that the Effects are ever proportionable to their

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QUUM Vim vivam dicam, quæ cum Motu actuali conjuncta est, (per ejus Definitionem) patet *eam Vim mihi in præsentiarum considerandam esse* de Vi viva acturo, *quæ jam corpori moto inest*; proindè abstraho a communicatione Motus, atque ad Vim eam solum adtendo, quæ corpori jam moto celeritate uniformi, vel æquabili, inest: hanc enim celeritatem in sequentibus intelligo.

their Causes, when those Effects are produced in the same, or equal Times. Now, since the Forces of Bodies in motion (*Vires Motrices*, or *insitæ*) do not increase or decrease in any Proportion with the Times of their (real, or pretended) Actions: if the Times of the Continuance of the Motions, or the Actions of those Forces must need be taken in the Account; those Times are to be suppos'd equal, since it would be not only absurd, but ridiculous, to compare Forces acting during unequal Times, and bring those unequal Times in the *Calculus*, notwithstanding that those Forces remain the same, whether they act during a longer, or a shorter Time. Therefore in the general Expression of our Author, §. 35. *viz.* $V : v :: Et : eT$, if by V and v he expresses two different Forces of Bodies in motion, (*Vires Motrices*, or *Insitæ*) the Times t and T must be supposed equal, from what has just now been said, in which case $V : v :: E : e :: CM : cm$, exactly the same as according to the old Opinion, which receives hereby a collateral Proof from these very Dynamick Principles of our Author.

5°. From thence it also appears evidently, that all that is contain'd in the first Chapter of our Author's Dissertation, (the four principal Theorems of which have been quoted above) wherein the Times T and t are supposed different, can never be affirm'd of the Forces of Bodies in motion, (*Vires Motrices*, or *insitæ*.)

6°. But if we suppose that in the *Paragr.* 35, and 56, of our Author, the Forces meant, and express'd by V and v, are such Forces as put Bodies in motion, or alter the Motion they had before, which always requires Time; that is, such Forces as Sir *Isaac Newton* calls *Vires impressæ*, and which he defines as follows, Book 1. Def. 4. "*An impress'd* "*Force is an Action exerted upon a Body, in order to change its State,* "*either of Rest, or of moving uniformly forward in a right Line.*—— "This Force consists in the Action only, and remains no longer in the "Body when the Action is over. For a Body maintains every new "State it acquires by its *Vis Inertiæ* only; impress'd Forces are of diffe-"rent Origins, as from Percussion, from Pressure, from Centripetal "Force." Then indeed the Times T and t, during which these Forces are

Philosophiæ Naturalis Principia Mathematica, Lib. 1. Def. 4. *Vis impressa est actio in corpus exercita, ad mutandum ejus statum vel quiescendi vel movendi uniformiter in Directum.*——Consistit hæc Vis in actione sola, neque post actionem permanet in corpore. Perseverat enim corpus in statu omni novo per solam Vim Inertiæ; est autem Vis impressa diversarum Originum, ut ex Ictu, ex Pressione, ex Vi Centripeta.

Annotat. Lect. VI. are suppos'd to act, are to be taken into the Account. And the Expression of those *Vires impressæ*, or impress'd Forces, will be as in our Author's §. 35. *viz.* $V : v :: Et : eT :: CMt : cmT :: \frac{CM}{T} : \frac{cm}{t}$.

7°. The Paralogism of our Author's Demonstration in his Parag. 56, is this; namely, that he introduces in this last Expression the Celerities C and *c*, instead of the Times *t* and T; this Substitution is never true, nor can it ever be allow'd, but in one single Case, *viz.* when by the Letters V and *v* are meant, (not Forces of Bodies already in motion, (*Vires Motrices vel insitæ*) because, as we have shewn in the 4th Remark, they follow no Ratio of the Times of their Actions or Continuance, but) impress'd Forces, (*Vires impressæ*) acting on the Body M and *m* thro' equal Spaces, and each of them always acting with the same Intensity. Then indeed the Celerities which the Bodies will have acquired at the end of those equal Spaces, being reciprocal to the Times of acting, we shall have $t : T :: C : c$, and instead of $V : v :: CMt : cmT$, we shall have $V : v :: C \times M \times C : c \times m \times c$; that is, the impress'd Forces, (*Vires impressæ*) which acted on the Bodies, during the Times T and *t*, thro' equal Spaces; and each of them acting always with the same Intensity, will be as the Squares of the Velocities into the Masses. But we cannot conclude from thence, (even in respect of the impress'd Forces) (*Vires impressæ*) that it is so universally; since that would be drawing a general Conclusion from a single particular Case. For if the Spaces (thro' which two different impress'd Forces V and *v* are acting on the Bodies M and *m* during the Times T and *t*) are different, the Celerities which the Bodies will have acquired at the end of those Times, will not be reciprocal to the Times; in which Cases the Substitution of C and *c* for *t* and T, cannot be introduced, and the Expression of these impress'd Forces will remain as before $V : v :: Et : eT$, or $V : v :: \frac{CM}{T} : \frac{cm}{t}$; that is, the impress'd Forces will ever be, as the Momenta which they give to Bodies divided by the Times during which they act to give it. Which Rule will hold true in all Cases whatsoever: But, as we have already said, we cannot in any wise apply the same Reasoning to the Forces of Bodies in motion, (*Vires Motrices* or *insitæ*) which neither encrease or decrease in any proportion of the Times of their Actions or Continuance.

8°. It seems that the whole Drift of our Author in this second Chapter, was to establish this Substitution of C, and *c*, for *t*, and T; in order to apply the same Reasonings, and employ the same Symbols to the Forces

Forces of Bodies in motion, (*Vires Motrices*, or *insitæ*) which he had made use of, treating of Forces in general in his first Chapter: he owns it, in some measure, in his Parag. 55. where he endeavours to illustrate his Demonstration of a reciprocal Ratio between the Times that a Body remains (*hæret*, as he calls it) in every Point of its Line of Direction, and its Celerity. These are his Words, " *As I am conscious the Proposition " just now demonstrated will be the chief and best Foundation of this Tract, " I will demonstrate it another way.*"

9°. In his §. 57. our Author charges all the Followers of the old Opinion, (under the Name of *Cartesians*) with neglecting the Ratio of the Times, in the Calculation of Forces, contrary to his Dynamick Principles, which he saith we do not disallow of. I have shewn in the fifth Remark with what Restriction his Dynamick Principles are to be allow'd; but as to what he charges us with, we are so far from being guilty of it, that it is in consequence of the Times being taken in the Account, that we maintain that the impress'd Forces (*Vires impressæ*) are as the Masses multiplied into the Celerities of the Bodies, which they put in Motion, if the Times during which they act are equal: and that those Forces are as the Products of the Masses into the Celerities, divided by the Times, if the Times of their Actions are different.

And it is also in consequence of a due regard to the Times, that we continue to maintain that the Forces of Bodies already in Motion (*Vires Motrices*, or *insitæ*) are always proportionable to the Momenta themselves; or, as the Products of the Masses into the Celerities: because whether the Times, during which those Forces are pretended to act on the Bodies, are *long* or *short*, the Bodies would produce the same Effect in every Instant of the Continuance of the Motion, and consequently the Forces inherent in those Bodies neither increasing or decreasing, in any Ratio of the Times, those Times must of course be supposed equal, or else thrown entirely out of the Expression of the Forces inherent in those moving Bodies. Our Author adds, before his Conclusion, that he could illustrate his Doctrine by a great many Examples, in Bodies not elastick, as well as elastick; but this he keeps for another Dissertation, designing this only as a general Demonstration of the Measure of Forces, deduced from the Principles of the Dynamicks, in which he is entirely confident to have succeeded; for he concludes with returning God Thanks (for his Success, as I suppose) in the following Words;

" *To God the Best, and Greatest, be given*
" *Praise, Honour, and Glory, for ever, and ever, Amen.*

Annotat. Lect. VI.

NOTWITHSTANDING this great Confidence of Success in our Author, if he wrote his Preface after his Dissertation, (according to the Custom of most Writers) he was then still dubious, whether this Demonstration (as he calls it) would be sufficient to bring over the Followers of the old Opinion to the new. For he says in that Preface, that in case this Dissertation should not have the desired Effect, " *he has four more " different Demonstrations of* Leibnitz's *(or the new) Opinion, whereby " (tho' he protests he is ready to receive the* Cartesian, *or the old Opinion, " whenever it shall be evidently demonstrated) his Mind is so strongly per- " suaded of the Truth of the new Opinion, and so well settled as to that " Point, that he scarce thinks he shall ever be made to alter in his Opi- " nion.*" And he further assures us, that " *in case This Demonstra- " tion shall fail of the desired (nay the expected) Success, he will give " those four Demonstrations to the Publick.*"

WHAT Success those four others may have, I will not so much as guess at; but I may venture to say, that this Dissertation is so far from a Demonstration of the new Opinion, that the Principles he has laid down to prove it, are more than sufficient to prove the old Opinion, as I have endeavour'd to make evident in the few Remarks I have added to the Account you desired me to give you of the Dissertation itself.

I am, with Respect,

Reverend SIR,

Your most Obedient,

Humble Servant,

CHARLES DE LABELYE.

P. S. OUR Author asserts in his Preface, that the Dispute about Forces is a Mathematical Dispute; but whoever will be at the trouble attentively and impartially to consider the fundamental Definitions given by

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PRÆSTO sunt quatuor aliæ diversæ Demonstrationes, quibus in veritate mensuræ Leibnitzanæ animus, ad Cartesianam recipiendam, si evidenter demonstrata fuerit, æque paratus, adeo est obfirmitus, ac stabilitus, ut vix putem unquam me inde dimotum iri.

ILLAS deinceps luci exponam publicæ, si hæc tractatio optato (imò & sperato) eventu caruerit.

by the Writers on both ſides of the Queſtion, will eaſily perceive that the Diſpute is hardly more than a nominal, or metaphyſical Diſpute; for, after all, it is very evident that what we mean by the Word *Force* is very different from what the Gentlemen who follow *Leibnitz*'s Opinion mean by the ſame Word. I conceive likewiſe, that, on account of the different Ideas that are joined to a Word of ſo *vague* (or looſe, and extenſive) a Meaning, as is the Word *Force*, it may happen that very different Concluſions may be drawn from thoſe different Definitions. And it is for want of a due Attention to thoſe different Definitions, that the Diſpute about the Meaſure of Forces has laſted already upwards of 40 Years. For the Diſpute is at an end, if it is obſerved that Forces ought to be diſtinguiſh'd into two Kinds; *viz.* that Force which we conceive to exiſt every Inſtant, in an Agent, (ſuch as a Spring, or a Body already in Motion) (which Force, in my Opinion, might retain the Name of *Vis inſita*, or inherent Force, and will always be found proportional to the *Momentum*, or Quantity of Motion which it can produce in the ſame Time) and another kind of Force; namely, that which the Gentlemen of *Leibnitz*'s Opinion conſider to be in an Agent, (ſuch as a Spring, or a Body in Motion) and which they meaſure by the total Effect which that Spring, or Body in Motion, is able to produce; till the Force, or the Motion, which produced that Effect, be totally deſtroy'd, without any regard to the Time employ'd in the Production of that Effect, or in the total Deſtruction of the Force which produced that Effect. I humbly conceive this Force might alſo keep the Name of active Force, (*Vis activa*) as it is called by Mr. *Leibnitz*'s Followers.——If due regard be had to this Diſtinction, it will be eaſy to ſhew in what Caſes Forces and their Effects ought to be conſidered in the former, or in the latter Senſe: why all the *Phænomena* can be accounted for, from either of the two Meaſures of Forces; and why ſome particular Experiments, which ſeem to favour either of the two Opinions, more than the other, are really conſentaneous to both, when due regard is had to the Diſtinction juſt now mentioned. But if, thro' the Obſtinacy of either, or both Parties, this Diſtinction is not allow'd of, and the Word *Force* muſt be abſolutely reſtricted to one Meaning only, the Diſpute will be meerly nominal, and each ſide of the Queſtion can bring Arguments equally concluſive, to ſhew why the Word Force ought to be underſtood in the Senſe that is moſt conformable to their reſpective ways of Computation.

NOW I come to conſider the Concluſions which are drawn from Pits made in Clay, or other ſoft Subſtances, by hard Bodies ſtriking againſt thoſe Subſtances.

Annotat. Lect. VI. It is certain that when ſpherical, cylindrick, or conick hard Bodies, have (by falling, or moving in any Direction) made Impreſſions or Pits on ſoft Subſtances which they have ſtruck, thoſe Pits have always been proportionable to the Square of the Velocity of the percutient Bodies. The Favourers of the new Opinion conſider thoſe Pits as the Meaſure of the Force of the moving Bodies that make them, eſtimating the Reſiſtance of the Clay to be as the Force of the percutient Body; and this is agreeable to their Definition of *Force*. The Reaſon why the Defenders of the old Opinion differ from them, is, that the ſoft Subſtances that receive the Impreſſion are by them conſider'd as Fluids; and then, tho' they allow the Reſiſtance made by Fluids to Bodies moving in them to be as the Square of the Velocity of the ſolid Body moving in the Fluid, they do not conclude from thence that it muſt be as the Force of the ſolid Body in other Caſes. The Reaſon why it happens ſo here, (ſtill conſidering Force as inſtantaneous Preſſure) is, that when the Body has a Velocity encreas'd (for example) double at one time of what it had at another, it will diſplace twice the number of Particles, (that is, twice the quantity of Matter) and drive each Particle twice as far, which therefore muſt make the Receſs of the Fluid (or of the ſoft Body) to be four times greater; that is, as the Square of the Velocity of the Percutient; tho' the Motion given to each Particle be but as the Velocity of the Percutient.

To make this clearer, let us conſider how Water acts upon the Ladle-Board of the Wheel of an under-ſhot Mill. When the Water iſſuing out at the Ajutage, or Diſcharge at the bottom of the Sluice, ſtrikes againſt the Float-Board, (or Ladle-Board) and in working the Mill produces a certain Effect; if that be obſerv'd, and afterwards the Head of Water in the Mill-Dam being four times higher *, the Water comes out of the ſame Ajutage with twice the Velocity that it did before, we find that the Effect of the Wheel is four times greater than before, (following the Proportion of the Square of the Velocity of the iſſuing Water) we muſt not ſay in general, that the Water ſtriking acts according to the Square of its Velocity, and conclude from thence, that the Stroke of percutient Bodies is as the Square of their Velocities. For when we conſider this Caſe rightly, we find that as the Water's Velocity is double, there are twice the number of Particles of Water that iſſue out, and therefore the Ladle-Board is ſtruck by twice the Matter, which Matter having twice the Velocity that it had in the firſt caſe, the whole Effect muſt be quadruple, tho' the inſtantaneous Stroke of each Particle is encreas'd only in a ſimple Proportion of the Velocity. Now, if inſtead of the Water ſtriking againſt the Ladle-Board, we ſuppoſe the Ladle-Board to move againſt the Water, we ſhall find that the Reſiſtance of the Water to the Ladle-Board will only be as the Square of its Velocity, becauſe with a double Velocity the Ladle-Board will remove twice the number of Particles of Water, and daſh each Particle twice as far. So that tho' the Reſiſtance be quadruple, it is only becauſe there are twice the number of watery Particles put into Motion, and each of them moved with twice the *Momentum*, (here call'd) *Force*, as the Velocity of the percutient Body is twice as great. If we conſider the Impreſſions

* See L. 7.

preſſions made by Solids on ſoft yielding Subſtances in this Light, all the Difficulty will be clear'd up.

THUS, which ever Opinion we make uſe of, provided we conſider the different Definition of the Word *Force*, we ſhall find that the Effect of the Water working an under-ſhot Mill, will be proportionable to the Square of the Velocity of the Water ſtriking againſt the Ladle-Boards of the Wheel; and that whatever Diſputes there may be about Words not well underſtood on either ſide, a Mill will be built in the ſame manner, and be of the ſame Advantage in the Uſes of Life, which way ſoever the Word *Force* be defin'd.

To conclude my Conſiderations upon this Subject, I will ſhew the Fallacy which has induc'd ſome People to believe, that *Bodies that fall by the Force of Gravity are accelerated with more Difficulty, than Bodies that are thrown upwards are retarded by Gravity*; becauſe I have known ſeveral ingenious Gentlemen make uſe of this Aſſertion in favour of the new Opinion; but when rightly explain'd, it does not want any ſuch Support.

THIS is their way of arguing—" When a Body begins to fall, the Cauſe " of Gravity acting upon it, from Reſt puts it into Motion, and gives it (for " example) one Degree of Velocity; then, to give a ſecond Degree of Velo- " city to the Body now in Motion, the Cauſe of Gravity muſt be carry'd after " the Body with the ſame Velocity that the Body moves, otherwiſe the Body " would receive no Impreſſion from it. Juſt as a Man who ſhould ſtrike a " Ball forward with his Hand, and give it one Degree of Velocity, cannot " ſtrike it again in the ſame Direction, unleſs ſome Power carry the Man for- " ward as ſwift as the Ball, in which caſe the moving Ball being at reſt in " reſpect to the Man, he may ſtrike it again, and add to it as much more " Velocity as he gave it at firſt. But when a Body is thrown upwards, it " continually meets the Cauſe of Gravity, which gradually deſtroys its Mo- " tion, and needs no other Help to put it in a condition to act upon the Body " which continually meets it, till all its Motion is deſtroy'd."

THIS would be true if the Cauſe of Gravity was an Impulſion, which ſome have ſuppoſed, thinking it to be Sir *Iſaac Newton*'s Opinion, becauſe he ſays, when he declares his Ignorance of the Cauſe of Gravity, *that he hath conſidered Attraction in a Mathematical manner, according to its Effects, and not its Cauſes, and that it may be an Impulſion for aught he knows.* But we ſhall ſoon find the Fallacy, if we conſider Gravity abſtractedly as we ought to do, and take notice of its real Effects.

LET us ſuppoſe A E to be a Line perpendicular to the Earth; that is, extended in the Direction which Gravity acts in from A towards E. If a Body being at reſt at A, is ſuppoſed to receive an Impulſion from the Cauſe of Gravity, ſo as to put it in Motion with any Degree of Velocity towards E, that Cauſe of Gravity which gave the Stroke at A muſt be carry'd towards B, otherwiſe it will not accelerate it, by adding any more Velocity to it, &c. Plate 8. Fig. 8.

THIS would be the caſe if the Action of Gravity was a Stroke; but ſince Gravity (or its Cauſes, as they term it) exiſts as well at B, or C, or D, as at A, there is no need of transferring it to B, and then to C, and then to D,

&c.

Annotat. Lect. VI.

Plate 8. Fig 8.

&c. to overtake the Body, and add to its Motion: for if you let go the Body at B, or C, or D, inſtead of A, it will begin to move downwards with the ſame Degree of Velocity, as well as ſetting out from A. And if you conſider Gravity acting either at A, B, C, or D, it will give the ſame Degree of Velocity downward to a Body at any of thoſe Points, whether that Body contains a ſmall, or a great Quantity of Matter; or whether that Body has at that time any Velocity downwards, upwards, in any Direction; or no Velocity at all: that is, whether the Body is at reſt, or in any degree of Motion. From hence it appears, that a Body acted upon by Gravity is juſt as eaſily accelerated as retarded.

N. B. In this Caſe I have not conſidered Gravity leſs at A than at E, becauſe A is farther from the Center of the Earth; it being ſufficient for my Purpoſe to conſider it acting downwards with equal Force, as it doth near the Surface of the Earth.

Plate 8. Fig. 9.

Ann. 11. [36.—*A general Calculation expreſs'd algebraically.*] Firſt of all we'll ſuppoſe A and B to move the ſame way, and let C expreſs the Velocity of the following Body A, whilſt c expreſſes the Velocity of the leading Body B; whence the relative Velocity of the Bodies will be $C - c$, and the Sum of the Motions towards the ſame Parts will be $AC + Bc$: let the Velocity of the Body A after the Stroke, going the ſame way that it went before, be call'd x; and, becauſe the relative Velocity of the Bodies remains the ſame before and after the Stroke, the Velocity of the Body B will be $x + C - c$; for the relative Velocity of Bodies is equal to the Exceſs whereby the ſwifter Body outgoes the ſlower, therefore that Exceſs muſt be $C - c$. But ſince the Velocity of the Body A is now x, its Motion towards D will be Ax; and ſince the Velocity of the Body B is $x + C - c$, its Motion the ſame way will be $Bx + BC - Bc$; and the Sum of thoſe Motions will be equal to the Sum of the former Motions; that is, $Ax + Bx + BC - Bc$, will be equal to $AC + Bc$; whence, by reducing that Equation, $Ax + Bx = AC - BC + 2Bc$; and $x = \frac{AC - BC + 2Bc}{A + B}$ = to the Velocity of the Body A. Moreover the Velocity of the Body B is $= x + C - c = \frac{AC - B + 2Bc}{A + B} + C - c = \frac{AC - BC + 2Bc + AC + BC - Ac - Bc}{A + B} = \frac{2AC - Ac + Bc}{A + B}$.

If BC be greater than $AC + 2Bc$, then will x, or $\frac{AC - BC + 2Bc}{A + B}$ become a negative Quantity, therefore the Velocity of the Body A will be directed the contrary way, and its Motion toward D will be negative. If the Body B be at reſt; that is, if c be $= 0$, the Velocity of the Body A after the Stroke will be $+ \frac{AC - BC}{A + B}$, forward or backward, according as the Sign $+$ or $-$ will prevail.

If the Bodies A and B, with the Velocities C and c, and contrary Directions, ſtrike one another directly, their Motion towards the ſame Parts will be $AC - Ac$;

A c; and the relative Velocity of the Bodies will be $C + c$. Now let x express the Velocity of the Body A after the Stroke; its Motion the same way as before will be $A x$; the Velocity of the Body B will be $x + C + c$, (for the relative Velocity of the Bodies is not chang'd by the Stroke) and the Motion of the Body B toward D will be $B x + B C - B c$; whence the Sum of the Motions the same way will be $A x + B x + B C - B c$, which (*by Rule* 1.) will be equal to $A C - B c$, and therefore it will be $A x + B x = A C - B C - 2 B c$, and $x = \frac{A C - B C - 2 B c}{A + B}$, and the Velocity of the Body B will be $\frac{A C - B C - 2 B c}{A + B} + C + c = \frac{A C - B C - 2 B c + A C + A c + B C + B c}{A + B}$ $= \frac{2 A C + A c - B c}{A + B}$. Annotat. Lect. VI. Plate 8. Fig. 8.

If $B C + 2 B c$ be greater than $A C$, the Motion of the Body A will be backward towards the contrary Part, in which Case x or $\frac{A C - B C - 2 B c}{A + B}$ will be a negative Quantity.

Several of these Constructions were originally Sir Christopher Wrenn's, *and* Christian Huygens's, *and further illustrated by some Demonstrations and Calculations of Dr.* John Keil; *from whom also I have taken great Part of these Annotations relating to the Congress of Bodies.*

LECTURE

LECTURE VII.

HYDROSTATICKS.

Lect. VII. 1. THE Science of *Hydroſtaticks* conſiders the Effects of the Gravity, Preſſion, Reſiſtance, and Motion of fluid Bodies; whether they are incompreſſible *, as *Water*, or compreſſible, as *Air*: as alſo the Action of Solids on Fluids, and Fluids on Solids.

* Ann. 1.

A *Fluid* is a Body that yields to any Force impreſs'd, and whoſe Parts by yielding are eaſily ſeparated from one another.

2. *All the Parts of a Fluid are heavy* at all Times and in any Situation; which it would be unneceſſary to mention, ſince all Matter is heavy, if a great many Perſons had not affirm'd, and given out as an Axiom, that *Elements do not gravitate in their own Places*; as for Example, that *Air does not weigh in Air, nor Water in Water*, &c. This Notion is built upon this Conſideration, *viz.* that when we draw up a Bucket of Water out of a Well, the Hand holding the Rope does not feel the Weight while the Bucket in the Well is under Water, but feels the whole Weight of it when it is brought up above the Surface of the Water in the Well. Now the Caſe is this; when the Bucket full of Water is under the Surface, the other Parts of the Water, (ſuppoſe ſo many imaginary Buckets full at the ſame height as the Bucket) endeavour to deſcend as well as the Water in the Bucket, and with the ſame Force, as ſo many Counterpoiſes to the Bucket, and therefore do not permit it to deſcend, which is the Reaſon that the Hand does not at that time feel the Weight of the Water in the Bucket. So that, tho' the Bucket of Water *weighs* in Water, it does not *preponderate* or *over-weigh* in Water. Thus, if one Pound be placed in one Scale of a Balance, and another Pound in the other, no Man can ſay the firſt Pound does not weigh, becauſe it does not deſcend or overweigh the other. But to take off all cavilling, this matter will be ſet in a clear Light by

EXPERIMENT 1. *Plate* 8. *Fig.* 10.

3. ON the End B of one Arm of the Balance A B is ſuſpended a Copper Ball C holding about a Gallon; after it has been exhauſted of its Air on the

the Air-Pump by its Cock: and having laid upon it the little Weight *p* of the 6th part of an Ounce, a Counterpoiſe P muſt be placed in the other Scale to make an Æquilibrium. Then turning the Cock of the Ball, let in the Air, and the Ball will become ſo much heavier, that you muſt take off the little Weight *p*, to reſtore the Æquilibrium. Lect. VII.

3. This ſhews that *Air weighs* in *Air*, a Gallon of Air weighing about the 6th part of an Ounce.

4. That *Water weighs in Water*, is ſhewn by

Experiment 2. *Plate* 8. *Fig.* 11.

C is a hollow Glaſs Ball holding about half a Pint, with a Braſs Cock to it, and ſo heavy, that when empty it will ſink in Water. Exhauſt it of its Air, and having, from the end A of the Balance A B, ſuſpended it under the Surface of the Water W W in the Jar I, make an Æquilibrium to it in the oppoſite Scale at P. Now, upon turning the Cock of the Ball under Water, the Water will ruſh in to fill the Place that had been exhauſted of Air, and the Ball will overweigh the Counterpoiſe P, as much as the Weight of the Quantity of the Water in the Ball. Which ſhews that *Water weighs in Water*. Plate 8. Fig. 11.

5. In order to facilitate ſeveral Demonſtrations and Explications of Phænomena in Hydroſtaticks, we are to ſuppoſe a Fluid in a Veſſel cut by ſeveral horizontal Planes, or imaginary Surfaces below the real Surface from Top to Bottom. As for Example, if the Veſſel N K (*Plate* 8. *Fig.* 12.) be fill'd up to A B, and you imagine the Water to be pour'd out as far as C D, as you do not actually do it, C D is not a real but an imaginary Surface. Such you may conceive at E F, G H, and ſo any where between A B and I K. Likewiſe if Water be pour'd on as far as L M or N O, A B that was the *real*, becomes now an *imaginary* Surface. Plate 8. Fig. 12.

6. Besides this imaginary horizontal Diviſion of a Fluid, we are likewiſe to ſuppoſe the whole Fluid in a Veſſel to be divided into perpendicular Columns, from the Top to the Bottom of the Fluid, either round or priſmatick of any Shape, according to the Surface of the Bodies preſs'd upon under Water; as for Example, in the Veſſel D E (*Fig.* 13.) A *a* is a round Column of Water, preſſing upon a round Surface, as a Piece of Money at *a*, B *b* a ſquare Pillar preſſing upon a ſquare Surface as *b*, and C *c* a Triangular Pillar or Column preſſing upon a triangular Surface, and into ſuch Pillars we may ſuppoſe the whole Fluid Plate 8. Fig. 13.

 divided,

Lect. VII. divided, according as we have occasion to consider the Fluid's Pressure upon different Bodies immers'd, or upon different Parts of an imaginary Surface.

PROPOSITION I.

Plate. 8. Fig. 13. 7. ALL the Parts of an homogeneous Fluid are at rest.

LET us consider in *Fig.* 12. the Fluid AK as divided into the 4 equal Parts AD, CF, EH, GK: as all those Parts are heavy *, and GK is at Bottom; EH having as much Matter, but no more Velocity than GK, has no more Tendency to go down than GK, and therefore cannot displace GK, but must remain upon it pressing it with all its Weight: thus CF will press upon, but not displace EH; the same may be said of AD in respect of CF. So that tho' the upper Parts press upon the lower, they cannot displace them or give them any Motion; contrary to what *Cartesius* affirm'd, *viz.* that *Fluidity consisted in a due Motion of the Parts.* Hence follows also, that *the higher the Fluid is in a Vessel, the more the Bottom of it will be press'd.*

* Nº. 2.

PROPOSITION II.

8. THE *real Surface, and all the imaginary Surfaces of a Fluid, are equally press'd in all their Parts.* Plate 8. Fig. 14.

Plate 8. Fig. 14. LET SS be the Surface of a Fluid, as Water, in the Vessel ABC; and let us consider that a Column of Air, as *a*SS*e*, presses from the Top of the Atmosphere down to the Surface SS. Now, if this Column of Air be divided into two Semi-Cylinders by a Plane passing along the Line *rq*, that which presses on the half S*q* of the Surface SS, being equal to that which presses on the other half *q*S, the whole Surface will be press'd alike on both its halves. Likewise if you suppose the Column of Air divided into any Number of equal Columns, they will every one press alike on that Base, or part of the Surface on which they stand. Likewise I say, that the imaginary Surface *ss* is press'd in all its Parts alike. The half Column *asor* is made of Air with a piece of Water at Bottom as S*o*; and the other half Column *rs* is likewise made of a Semi-Cylinder of Air, with the Water *qs* at its Bottom. Now, since these Semi-cylindrick Pillars are each of them the half of the whole compound Column *asse*, they must press equally each upon the Base which they stand upon; and so would any Number of Columns upon any Number of equal Bases into which the imaginary Surface is divided.

COROL-

COROLLARY.

9. HENCE follows that the Surface of a Fluid will always have an horizontal * Position when left to it self, and if any part of it be put out of that Situation, it will return to it again. * Annot. 2.

EXPERIMENT 3. *Plate* 8. *Fig.* 15.

HAVING immers'd the Tube 1 in the Water *s s* of the Vessel ABCD up to its Part *a*, put your Thumb upon its Part 1, and lift up the Surface of the Water in the Tube *a* to above *s s*, the Surface of the Vessel or Jar. As soon as you take off your Thumb, the Water in the Tube will subside, and after some Vibrations settle at the Surface *s s*. For if the Water continued at *a*, the Surface *s s* wou'd in that place be more press'd by a Column of Air, having at Bottom the piece of Water *a s*, than by the respective Columns of Air of the same Diameter, which, without any Water join'd to them, press upon the correspondent Parts of that Surface: Therefore the Surface will yield under *a*, till the Water in the Tube descends to *s s*. For the same Reason the Water in the Tube 2, whose Surface may be kept at *b*, while the Thumb is upon the Mouth 2, will not continue in that Place as soon as the Thumb is taken off, but rise up to *s s*, because the imaginary Surface *k l* will be less press'd at *b*, than in any other part of it, as long as the Water continues every where below *s s*; otherwise, the imaginary Surface in the Plane *mn* is more press'd at *m* by the Column *s n*, than at *n* by the shorter Column *b n*, the other Columns also in the whole Vessel above the said imaginary Surface, having their Length and Pressures as *s n*; consequently they must push up the whole Fluid, till it rises in the Tube 2, up to the common Surface *s s*, to make the Pressure equal upon every part of the imaginary Surface *m n*. This will be further shewn by the following Plate 8. Fig. 15.

EXPERIMENT 4. *Plate* 8. *Fig.* 15.

TAKE a Tube of about an Inch Diameter, as 7, and having tied a flexible piece of Bladder to its Bottom, fill it with Water up to *g*, and immerging its End in the Jar below the Surface *s s*, the Water will push out the Bladder at the Bottom of the Tube into a Convexity, which shews that the imaginary Surface under the Bottom of the Tube is press'd downwards; but if the Surface of the Water in the Tube be brought down to the Surface in the Jar *s s*, the Bladder will be even at the Bottom of the Tube, as 8, which shews the Pressure on that part of the imaginary Surface to be neither greater nor less than in any other part; but if the Surface of the Water in the Tube mark'd 6, be brought to *f* below the Surface *s s*, the Bladder at the Bottom of the Tube will rise concave, which

Lect. VII. ſhews, that in that Place the imaginary Surface is leſs preſs'd than in its other Parts, becauſe the Water riſes upwards. The lateral Preſſure does alſo act in the ſame manner, as appears by tying a Bladder to a Tube cut obliquely, where the Bladder riſes concave, the Water being at *c* in the Tube 3, but is convex the Surface being at *d* Number 4, and flat at Number 5, when the Water is at *h* even with the Surface of the Jar, Numb. 5.

Proposition III.

10. Fluids preſs differently from Solids; for whereas Solids preſs only downwards, Fluids preſs every way, as appears by

Experiment 5. *Plate* 8. *Fig*. 16.

Plate 8. Fig. 16. On a Plane repreſented by the Line P*p*, lay a Drop of Water, as *a b*; then if you preſs it with your Finger, it will not only act on the Part *c* under it, but it will ſwell out and flatten ſo, as to act equally on the Parts at *a* and *b*; but if that Drop of Water was frozen, or inſtead of it there was a round Body, as for Example, a Shot of Lead, then the Preſſure would only be on the Part *c*, and the Re-action upwards againſt the Finger.

Definition. *Fig*. 17.

Plate 8. Fig. 17. 11. *Specifick Gravity* is next to be conſider'd and explain'd. One Body is ſaid to be *ſpecifically heavier* than another, when it *contains more Matter than another under the ſame Bulk*; as for Example, the Cube of Lead A contains more Matter, than the Cube of Wood B; or when it contains as much Matter under a leſs Bulk, as when the ſaid leaden Cube A weighs as much as the large wooden Cube C. This is alſo call'd the *Denſity* of a Body.

Experiment 6. *Plate* 8. *Fig*. 18.

Fill the Jar ABCD up to SS with Water, a little ting'd with red, ſo as not to loſe its Tranſparency; then having taken up from the Jar of Oil of Turpentine of Figure 19. the Column of Oil *m n*, plunge it into the Jar of Figure 18, and the Oil will ſtand at *m* above the Surface S S, one tenth Part of the whole Column *mn*, when you have taken off your Thumb. The Reaſon is, that as the imaginary Surface *s s* muſt be preſs'd in all its Parts alike, the Column of Oil *mn* being ſpecifically lighter than Water, muſt be taller than the correſpondent Columns of Water as *o p*, in order to weigh as much; and by that difference of Height is found the comparative ſpecifick Gravity of the two Fluids:

Plate 8. Fig. 18.

For

For—As the height of the Water : is to the height of the Oil : : ſo is the ſpecifick Gravity of the Oil : to the ſpecifick Gravity of the Water. Lect. VII.

THEN if ABCD (*Fig.* 19.) be fill'd with Oil of Turpentine up to SS, *op* will repreſent the Columns of Oil, and *m n* muſt be Water ting'd with red to make it diſtinguiſhably viſible, which in that caſe will always ſettle one tenth of the whole Length lower than SS, the Surface of the Oil. And here will be found the ſame reciprocal Proportion between the ſpecifick Gravities of the two Fluids and their Heights. That is *m n* : is to *p o* : : as the ſpecifick Gravity of the Oil : is to that of the Water. If the Oil in *Fig.* 18. be put down lower than *m* (as for Example, as low as the Surface SS) it will always riſe up again to *m*; and if it be higher than *m*, the Oil will come out at *n* the Bottom of the Tube, tho' the Drops of Oil riſe again up to the Surface of the Water *. On the other hand, the red Water in the Tube at *Fig.* 19. tho' it be rais'd up from *m* to S S, will always come down again to *m*, the Overplus going out at the Bottom of the Tube at *n*, and dropping down thro' the Oil to the Bottom of the Veſſel or Jar. Plate 8. Fig. 19. * Ann. 3.

PROPOSITION IV.

12. *Fluids preſs in all manner of Directions*, and that with a Force proportionable to the Height of the Fluid.

EXPERIMENT 7. *Plate* 8. *Fig.* 20.

IF ſeveral Tubes, of different Figures, ſuch as 1, 2, 3, 4, have their lower Ends immerg'd below S S, the Surface of the Water in the Veſſel A B C D, the Water coming in at their lower Ends in different Directions, will riſe up to the ſame Height, *viz.* up to S S in every one of them. If Oil be ſuſpended in the Tubes before they are immerg'd, upon the Removal of the Thumb from the Top of the Tube, the Oil will riſe up in every one of the Tubes to the ſame Height, but above the Surface of the Water, in proportion as the Oil made uſe of is ſpecifically lighter than Water. If the Veſſel be fill'd with Oil, and colour'd Water be uſed in the Tubes, the Experiment will be the plainer, the Water riſing equally high in all the Tubes, but not ſo high as the Surface of the Oil in the Veſſel, in proportion as Water is ſpecifically heavier than that Oil. Plate 8. Fig. 20.

PROPOSITION V.

13. THE ſeveral Solids that ſwim in Water, have their ſpecifick Gravities as their Parts immers'd.

EXPERIMENT

EXPERIMENT 8. *Plate* 8. *Fig.* 21.

Plate 8. Fig. 21. TAKE two Cylinders of Wood equal in Diameter and Height; for example, 10 Inches long, and one Inch in Diameter, the one as F *f*, made of Fir; and the other as O *o*, of Oak; and immerging their Ends in the narrow tall Jars of Water A B and C D, they will ſink differently, according to their ſpecifick Gravities, F *f* ſinking only the Depth S *f*, while O *o* ſinks the Depth *ſ o*; the ſpecifick Gravity of Fir: being to that of Oak : : as S *f*: is to *ſ o*. All ſorts of Wood, which are ſpecifically lighter than Water, may be thus tried.

WHEN a lighter Fluid preſſes upon a heavier, if any Part of the Surface of the heavier Fluid be freed from the Preſſure of the lighter Fluid, the heavier Fluid will be preſs'd up in that Place, and riſe up towards the Surface of the lighter Fluid, but ſhort of it in proportion as its ſpecifick Gravity is greater.

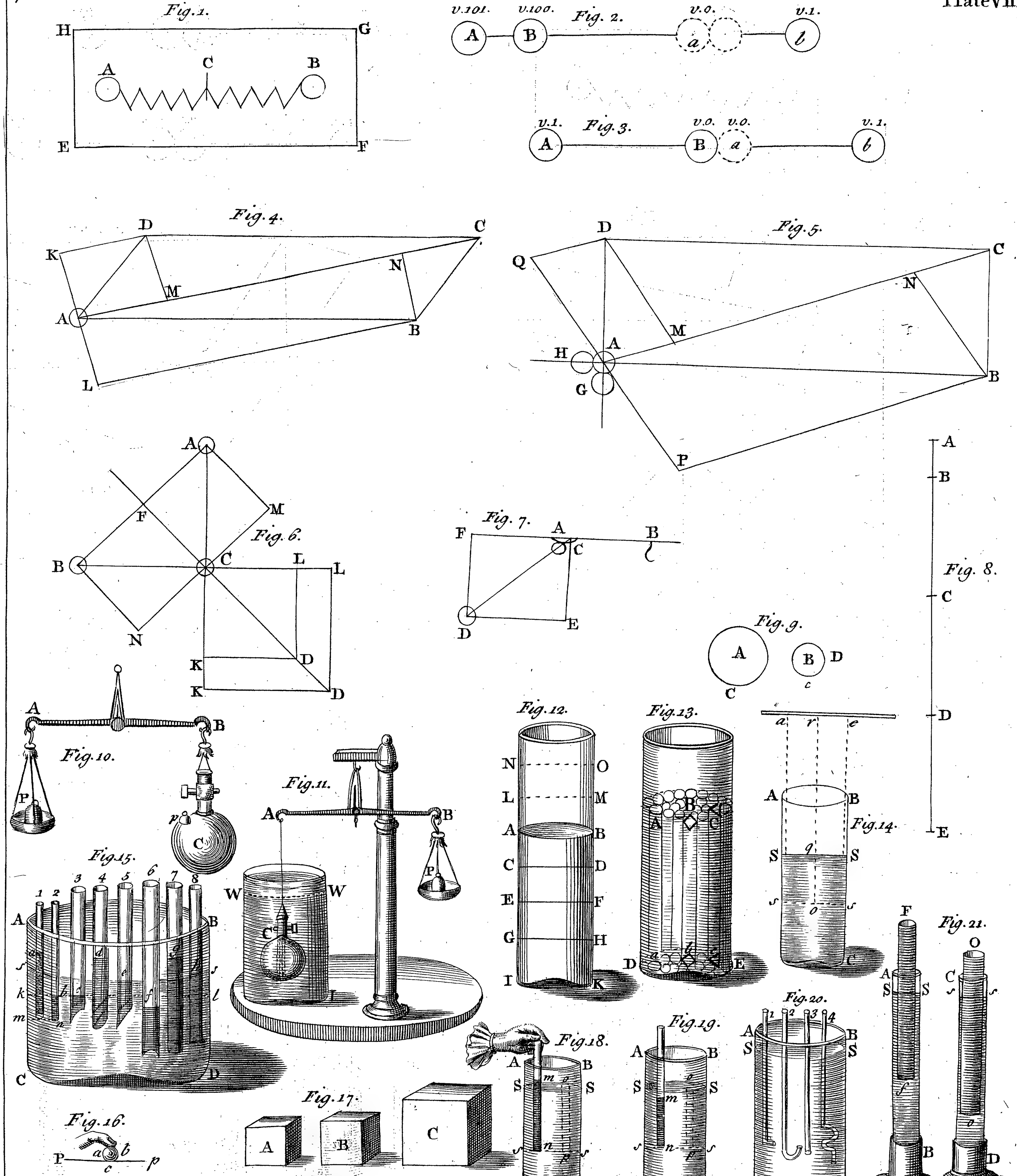
EXPERIMENT 9. *Plate* 9. *Fig.* 1.

Plate 9. Fig. 1. INTO the Jar A B pour colour'd Water up to S S, and put the open Tube *e f* in the middle of it; then pour on Oil of Turpentine as far as *s s*, and its Preſſure will make the colour'd Water go up into the Tube to *f*, where it will preſs upon the Surface S S, as much as the Oil would have done in the Tube, if it had fill'd it up to *s s*: for if the Tube be lifted up ſo as to let the Water drop out of it, and then put down again, the Oil will come into it as far as *s s*. But if the empty Tube with the Thumb upon its Top be plung'd thro' the Oil into the Water; upon taking off of the Thumb, the Water will by the Action of the Oil be preſs'd up to *f*.

EXPERIMENT 10. *Plate* 9. *Fig.* 2.

Plate 9. Fig. 2. THE Jar C D having Quick-ſilver pour'd into it as far as S D, put in the open Tube *g h*; then pouring Water up to C to a Depth of 14 Inches, the Quick-ſilver will, by the Preſſure of that Water, be rais'd up an Inch in the Tube, *viz.* up to *h*, where it will preſs as much upon the Surface S D, as the whole Tube full of Water would do. Now let us ſuppoſe C D to be a Well, in which there is Water up to S D, and C D to repreſent the Air or Atmoſphere preſſing into the Well, and *g h* the Pipe of a Pump. If you draw out the Air from the ſaid Pipe, ſo as to prevent its preſſing in it, the Water will riſe up to *h* in the Pipe, to preſs as much as the Air did before, the Height of the Water being proportionable to the Preſſure of the Air on the correſpondent Parts of the

Plate VIII



J. Mynde sc.

the Surface. This is the Foundation of the raising Water by Pumps, as will be farther ſhewn *. Lect. VII.

* Ann. 4.

PROPOSITION VI.

14. A Body ſpecifically lighter than Water will always emerge, ſome Part of it coming up above the Surface of the Water: but a Body ſpecifically heavier will ſink in Water; and a Body of the ſame ſpecifick Gravity as Water will remain at reſt in any part of the Water.

EXPERIMENT 11. *Plate* 9. *Fig.* 3.

TAKE a Cube of Oak 1, and having immerg'd it in Water, ſo that its Top is in the Surface A B, and its Bottom on the imaginary Surface C D; as ſoon as it is left to itſelf, it will riſe up to 3, becauſe when it is at 1, the imaginary Surface C D will be leſs preſs'd by the wooden Cube weighing (for example) half an Ounce, than by the Water whoſe room it takes up, which weigh'd an Ounce; but when the Cube is at 3, it only diſplaces a Bulk of Water of half its Bigneſs, and equal to it in Weight; and it will remain in its Place, becauſe then that Part of the imaginary Surface under the Cube will be equally preſs'd, whether the Cube be there or not. If the Cube was at 2, the imaginary Surface E F would be leſs preſs'd under the Cube than any where elſe; becauſe the Column 1, 2, would weigh leſs than a Column of Water of the ſame Bulk, the Cube of half an Ounce Weight diſplacing an Ounce of Water: ſo that it will riſe in the Direction 2, 1, till the Cube emerges above Water, as you ſee it at 3. Now if there be a Cube of Lead of the ſame Bulk as an Ounce of Water, it will weigh about 11 Ounces. If ſuch a Cube be plac'd at 4, or at 5, the imaginary Surface C D, or E F, under it, will be more preſs'd in that Part than any where elſe, and the Cube will deſcend in the Direction 5, 6: for as it weighs 11 Ounces, and the Water diſplac'd weigh'd but one Ounce, it muſt deſcend with the Force of 10 Ounces, the Difference between its Weight, and the Weight of an equal Bulk of Water. But if the Cube be of the ſame ſpecifick Gravity as Water, (as, for example, a Cube of green Box Wood) it will remain in any given Poſition; becauſe, wherever it be plac'd, it will not preſs the imaginary Surface more than the Water which it diſplaces. Plate 9. Fig. 3.

COROLLARY.

15. HENCE may be drawn a Conſequence, which ſeems to contradict it, but in reality is a Confirmation of, what has been prov'd; *viz.* That a Body ſpecifically heavier than a Fluid may be made to ſwim in that Fluid;

Lect. VII. Fluid; and a Body specifically lighter may be made to lie at Bottom. See the following

EXPERIMENT 12. *Plate* 9. *Fig.* 4.

Plate 9. Fig. 4. P is a Plate of Lead weighing 11 Ounces, and in Bulk equal to an Ounce of Water. By the String *c d*, fasten'd to it, let it down into the Water of the Vessel S *s m n s* S, twelve times its own Thickness below the Surface S S, (which here will be six Inches, the Plate being half an Inch thick) to bear on the imaginary Surface P *n*. In this case, the imaginary Surface will be unequally press'd; for at *d* the Column Q *d r* may be consider'd as made up of 11 Half-Inch Plates of Water, weighing each an Ounce, and the Plate of Lead at Bottom weighing 11 Ounces, so that the whole compound Column will weigh 22 Ounces: whereas other Columns of the same Base, as S P Q, bearing on equal Parts of the imaginary Surface above-mention'd, as they are made wholly of Water, (that is, 12 Plates of Water of the Bigness of P) will weigh but 12 Ounces; and consequently the Surface will yield at P, and the Plate fall. But if by any Instrument (such as A *d* made of a Tube screw'd to a Cupping-glass) the Water be kept from pressing at top of the Plate P, then the Column Q P *d r* will be chang'd into the short Column P *d*, which, instead of 22 Ounces, weighs but 11, and will be push'd up by that Part of the imaginary Surface under it; since all the other correspondent Parts of the said Surface are press'd more; *viz.* by Columns of Water weighing 12 Ounces. The way to make the Experiment is to have the Plate P cover'd with wet Leather, and held hard against the lower Edge of the Cupping-glass, by the String *c* A *d*, till the Plate P is immers'd 12 times its Thickness under Water, or deeper, when the Plate will swim, being push'd upwards without any help from the String. But if you should let go the String before that Depth, the Plate would come off, and fall as at *p*; because then the imaginary Surface *s s* would be more press'd by the Plate *p* alone, than by any other correspondent Column of Water, such as *r z y z* *.

* Ann. 5.

Plate 9. Fig. 5. To the Bottom of the little Jar A M *g g* M, *Fig.* 5. is cemented a Glass Plate *g g*; then a short Cylinder of Ivory I I, by a Wire fasten'd to its Middle, is laid close on the Glass Plate, and held down till Quicksilver be pour'd on over the Ivory up to M M. Upon taking off the Finger from pressing the Top of the Wire at K, the Ivory, tho' specifically lighter than Mercury, will remain at Bottom, because the close Contact of the Ivory with the Glass excludes the Mercury from insinuating itself under to push it up. For if by moving the Wire at K, one side of the Ivory be ever so little lifted up, the Mercury will immediately get under,

under, and make the Ivory swim at top. If then the Ivory be press'd Lect. VII. down again thro' the Mercury, so as to apply itself closely to the Glass, and exclude the Mercury, it will remain at bottom. Thus will Cork be made to lie at the Bottom of a Jar of Water, as appears by

Experiment 13. *Plate* 9. *Fig.* 6.

At the Bottom of the Jar A is fix'd a Brass flat smooth Plate as *b*, a Plate 9. Fig. 6. little oil'd at top. Then with the Machine A *d* of Figure 4, is to be push'd down to the above-mention'd Plate the round Cork C, which has a smooth Brass Plate oil'd fix'd to its under side. When the two Plates are together, so that Water cannot insinuate between them, fill the Jar with Water up to S S, and the Cork will remain in its Place at Bottom. But if with a Stick you move the Cork aside, that the Water may push up under it, the Cork will immediately rise to the Top.

Proposition VII.

Fluids in different Receptacles, as Lakes, Ponds, Wells, or Vessels of any kind, will stand at the same Level if they communicate with each other.

Experiment 14. *Plate* 9. *Fig.* 7.

Into the middle of the Bottom of the Glass Cup A B communicating Plate 9. Fig. 7. by a side Pipe, Cock and Joint, with the upright Glass Tube D E, screw the Glass Tube G B bigger in Diameter than D E; then pouring Water in at G up to H, it will rise up to the same Height I in the Tube D E. Let the Tube D E be mov'd on its Joint towards F, and the Water will rise to F, where the Quantity of Water F *m*, tho' greater than *l* I, will press no more than *l* I, because the Line *m* F may, in this Obliquity of the Tube, be consider'd as an inclin'd Plane, which takes away from the absolute Gravity of a Body in proportion to its Inclination *, as has been shewn †. Shut the Cock C, after having thro' G fill'd D E up to I; then screw out the Tube G H, and fill the Cup to SS. As soon as you open the Cock to make a Communication between the Tube D E and the Cup, the Water in the Tube will subside from I to *i*, raising the Water at S S, till both are level, tho' the Water in the Cup be 3 or 400 times more in Quantity than that in the Tube; which confirms what we have said, *viz.* that Fluids press according to their Height, and not their Quantity. So that in the Glass Cup you are only to consider in the Middle a Column of Water of the same Diameter as *l i* for its Counterpoise, while the other Columns which make the rest of the Water in the Cup, are supported by its Bottom.

* Ann. 6.

† L. 3. N° 48.

Lect. VII.

16. This is the Foundation of the famous hydroſtatical Paradox, *viz.* that *if there be ſeveral Veſſels, as* A B C D, E *c d* F, and *b i c d k*, (*Fig.* 8.) *of the ſame Baſe, and the ſame Height, but of very different Contents, fill'd full of Water, all their Bottoms will be equally preſs'd.* Let A D contain a Pint, which weighs a Pound; E *d* contain a Quart, which weighs two Pounds, and *b c* half a Pint, which weighs half a Pound: I ſay, the Preſſures upon the Bottoms C D, *c d*, *c d*, will be the ſame. And firſt we will ſhew it of the Veſſels A D and E *d*. If in the Veſſel E *d* we conſider the Cylinder of Water *a c d b* perpendicular over the Baſe, that Cylinder is equal to, and as heavy as, the Cylinder of Water in A D, and conſequently preſſes neither more nor leſs. If you ſuppoſe the reſt of the Water round about the top of this Cylinder at E *m a*, and F *n b*, to be frozen, the Caſe will not be alter'd; for then the Ice will make up Part of the Veſſel. Now if we ſuppoſe the Water thaw'd again, but unable to come within the Cylinder *a d*, its Preſſure will not be alter'd, becauſe that Cylinder will neither be higher nor denſer from any lateral Preſſure of the Water round its Top; nor will the Fluid be put into any Motion by that Communication, as has been ſhewn. And as Water is not compreſſible, if any Part of the lateral Water ſhould be by any means puſh'd into the Cylinder *a d*, that could not be done without puſhing out as much of the Water of the Cylinder, which would no way alter its whole Weight acting upon the Baſe. Therefore only that Cylinder preſſes upon it, while the reſt of the Water is ſupported by the Sides of the Veſſel E *m* F *n*.

Plate 9. Fig. 8.

It is not ſo eaſy to ſhew how the half Pint of Water in the Veſſel *b c* will preſs as ſtrongly as the Pint of Water in the Veſſel A B; but we will explain it ſo many ways as to give Satisfaction to ſeveral Readers.

If the Bottom of the Veſſel is ſuppoſed to move upwards from *c d* to *e f*, the Water being then no higher than *g*, the Water will riſe in the ſame time from *g* to *b*, with a Velocity reciprocally proportionable to the Quantities of Water contain'd between *c d* and *e f*, and between *g* and *i k*; which Quantities of Water will have the ſame Momenta, according to mechanical Principles *. If, inſtead of *g*, the Water is up at *b*, while the Bottom is ſuppos'd to riſe, the Velocity of the Water iſſuing at *b* will likewiſe be ſo much greater in proportion to its Quantity, as to reſiſt as much as the Top of the Water in the Veſſel A D, whoſe Velocity would be as much leſs, as its Quantity of Matter would be greater. Conſequently, as Action and Re-action are equal, the Bottom *c d* muſt be as much preſs'd by the Reſiſtance of the Water at *b*, tending to go out with a great Velocity at *b*, as by the Reſiſtance of the Water, tending to go out

* L. 2. No 3.

out of the Vessel A D, at A B, with a Velocity so much less as the Section of the Vessel A D at A B is greater than the Section of the small Vessel at *b*. Lect. VII.

Otherwise. Plate 9. Fig. 9.

THIS may be illustrated by representing the Columns of Water in the two Vessels by Glass Tubes. If 12 Glass Tubes a Foot long, as G, be taken to represent the Water in the Vessel A D, and 11 Tubes six Inches long, with one in their Middle 12 Inches long, as *b c d* L, be taken to represent the Water in the Vessel *b c*, and these two Parcels of Tubes be placed in the different Scales of a Balance, to represent a Pint of Water contain'd in A D, and half a Pint of Water contain'd in *b c*, G will certainly overweigh the Tubes in the opposite Scale by half a Pound. But if you take leaden flat Plates with an Hole in them, (as *l l*) and put them on upon the middle Tube H at *a b*, till there be so many on as amount to half a Pound; then the compound Mass of Glass Tubes and leaden Plates will make an Equilibrium with the Tubes in the opposite Scale G. Then if you take off all the leaden Plates from L but one, and hold your Hand over it, as is represented at *b c d*, tho' the opposite Scale hanging at B, with the Tubes G, will preponderate, yet will not the Scale at the End A be suffer'd to rise, because the Hand keeps it down. Now the Plate being held down does the same thing as *i k*, the solder'd Top of the Vessel *b c*, *Fig.* 8. Further, if you consider the Columns of Water in the Vessel of *Fig.* 10. it is plain that the middle B of the Base *b* C is press'd as much by the Column A B, as if the whole Vessel was a Cylinder, as *a* C; but it does not at first appear that the other short Columns, as *c* C, press as much as A, till you consider as follows. Suppose an Hole to be in the Top of the Cylindrick Part of the Vessel, as at *c*, it is evident that the Water pour'd in at A would come up to D, if there was a Tube to carry it up. Now let *c* be shut by the Cover *c d*, and the Water will act upwards against it with a Force equal to the Column of Water, as *c* D: and since Re-action is equal to Action, the Top of the Column *c* C will be press'd downwards with the Force of the Column D *c*, which Pressure, added to the Pressure of the Column of Water *c* C, will make the whole Pressure equal to the Pressure of the Column A B. The same may be said of all the other short Columns, which, by the Re-action of the Top *d c*, will act as if they reach'd up to *a* D, and the whole Vessel was a Cylinder. Plate 9. Fig. 9.

Another Way. Plate 9. Fig. 11.

Plate 9. Fig. 11.

THIS Action and Re-action of the Surface of the upper Part of the Cylinder *d c*, (*Fig.* 10.) may be further illustrated, by considering the spherical Figure of the Particles of Water. Let T V *t u x* (*Fig.* 11.) represent the Vessel above-mention'd: the perpendicular Column of Particles T *t* presses the horizontal Column of Particles *t u*, towards *u* and V, in proportion to the Height of *t* T : *t u* presses the Particles *u x* upwards against *x*, with the Force of *t* T *minus* the Weight of *u x* ; that is, with the Force *xy*, with which the Water would rise up, if there was an Hole at *x*. Now let the Bottom of the Vessel, which was in the Line B B, be remov'd to Z *w*, and then *t u* will press the Particles *u w* against *w* with the Force of T *t*, which added to the Pressure of the short Column *w u* will give a Pressure on *w*, as $T\,t + u\,w =$ equal to $T\,t + t\,o$, the Pressure of the whole Height of the middle, or highest Column of the Vessel.

FOR a mechanical Solution, make the following

EXPERIMENT 15. *Plate* 9. *Fig.* 12.

Plate 9. Fig. 12.

JOIN together the recurve Cupping-glass *m n*, and the Tube *o e*, by a Brass Joint I, so that the Tube and Cupping-glass may be parallel, or make any Angle with each other, as at Figure 13 and 14. where we have not drawn the Joint, but only suppose it. An Inch of Water at *c o* in the Tube will keep in Æquilibrio an Inch of Water in the Cupping-glass at *m n*, tho' twenty times greater in Quantity, because if the Water in the Cupping-glass descends from the Level *a b* to *p d* one Inch, the Water *c o* in the Tube will rise to *e f* twenty Inches in the same time, having the same Momentum as *m n* ; because those Quantities of Water have their Velocities reciprocally proportional to their Matter. Therefore the Water will be at rest, equal and contrary Forces destroying each other. In Figure 13. if the Water moves laterally from *a b* to *c d*, the Surface of Water in the Tube at *g h* will go to *e f* with as much more Velocity as it has less Matter, and consequently as much Momentum or Force.

LASTLY, in Figure 14. where the Tube and Cupping-glass are reduc'd to the Form of the Vessel *b c d* of *Fig.* 8. it is plain that if the Water of the Bottom *a b* rises up to *c d*, it will make the Water of *g h* rise up to *e f* with so great a Velocity as to have a Momentum equal to that of *a b*. And this is the reason why the Water in the small Tube at top (see A, *Fig.* 10.) will by its greater Velocity press as much down-

wards

wards towards the Bottom, as a Column D *d* of the Diameter *a* D, with a Velocity proportionably leſs. This will be made very ſenſible by Lect. VII.

EXPERIMENT 16. *Plate* 9. *Fig.* 15, 16, and 17.

THE Machine for the Experiment is as follows. A (*Fig.* 15.) is an hollow Braſs Cylinder of 2 ½ Inches Diameter bored ſmooth on the Inſide with a flat Bottom, having only a ſmall Hole to open and ſhut at *s* upon occaſion. S is an Iron Screw to ſcrew into a Board, as B X, (*Fig.* 16, and 17.) to bring down the Bottom cloſe to it. There is a Braſs Piſton, as C D, made of a Shank C *o*, a Braſs Plate C *e e* ſcrew'd to another Plate ſomething wider, as D, with an oil'd Leather between them *e e*, whoſe Office is to fold upwards, when the Piſton is in the Cylinder, ſo as to let no Water ſlip by, or come down to the Bottom of the Cylinder, and run out at the Hole *s*, which muſt be left open in this Experiment. The Braſs Cylinder being ſcrew'd to its Board, as at A B, *Fig.* 16. the Piſton C is put into it, and the Wire G O is ſcrew'd to its Top *o*, after which the Cover B E being put over the Wire, the Braſs Tube F *e* is ſcrew'd on at E, and Water pour'd in to the Top of the Tube, as in *Figure* 17. Then hooking one End of the Beam of a Balance to G, the Top of the Wire of the Piſton, put a Counterpoiſe in the Scale hanging at the other end of the Beam, till the Water juſt comes out at F, which ſhews how much the Water preſſes on the Piſton in the Cylindrick Box E A. Take off the Cover and Tube E D F, and inſtead of them ſcrew on a Cylinder of the ſame Height *a* B *b*, as on the 16 *Fig.* on the Left of *Fig.* 17. and hang on the Scale Beam. Now tho' the Quantity of Water in the Cylinder be 10 times greater than it was in the Machine at Figure 17, yet the ſame Counterpoiſe will raiſe the Piſton. Then take off the Cylinder, and ſcrew on the ſpreading Veſſel, or truncated Cone B D, which holds 20 times as much Water as the Machine of *Fig.* 17. and ſtill the Water will preſs no more, but the Piſton will be rais'd up by the ſame Counterpoiſe. Plate 9. Fig. 16, 17, and 18.

N. B. THE Friction of the Piſton, (which adds to the Preſſure of the Water) being the ſame in every Caſe, makes no Alteration in the Experiment, which plainly proves that very different Quantities of Water incumbent on the ſame Baſe, preſs it equally, provided their Heights are equal.

EXPERIMENT 17. *Plate* 10. *Fig.* 1.

17. ANOTHER Experiment to prove the hydroſtatical Paradox may be explain'd, without any previous Knowledge of hydroſtatical Principles; only from the common Obſervation that in all communicating Plate 10. Fig. 1.

Veſſels,

Lect. VII. Plate. 10. Fig. 1. Vessels, Water will rise to the same Level. ABIDc is a kind of Bellows made of two thick oval Boards about 16 Inches wide, and 18 long, join'd together with Leather to open and shut like a Pair of Bellows, but without Valves, only a Brass or Iron Pipe PpI to come in at the Bottom. Upon the upper Board CD put six half hundred Weights, W, W; and then pour in Water into the Pipe Pp, to the Height of 3 Foot, that is, to L, and that Water by running into the Bellows, will push up all the Weights, provided there be Water enough in the Bellows to keep its Boards asunder, and the Pipe be full. In this case, the Water in the Pipe which weighs but a quarter of a Pound, sustains 300 Pound weight; and this is the Reason: Let us suppose a Pipe Cc screw'd on at c; it is evident that the Water pour'd in at P, will rise up to C to the Line lML, where it will be level with the Water in P. If you suppose Pipes at E, and at F, the Water pour'd in at P will also fill them up to e and f; and if those Pipes being taken off, any Person stopp'd their Holes c, E, F, with his Fingers, each Finger stopping an Hole, would be push'd upwards with a Force able to raise up a quarter of a Pound, (the Weight of the Water that wou'd fill the Tube;) and since we may suppose such Tubes in every Part of the Board c D, (which is the same as one great Tube cLMD, containing them all) there must in every Part of that Board of the bigness of the Base of such a Tube, be a push upwards able to lift a quarter of a Pound (to fill a Tube supposed in that Place) and the Sum of all those quarters of a Pound is the Weight of all the Tubes, or of the Cylinder cLDM containing them all. So that whatever be the Bigness of cD, it will rise in proportion to the Height of the Water in the Tube Pp. If the Water stand at Dd a Foot above p, one hundred weight will be lifted on cD; if it stand at the Line *mo* two Foot high, cD will sustain 200 Pound; and if at the Line Ll, CD will sustain 300 Pounds. This is further illustrated when the Bellows is able to open a Foot, because then by pouring Water in at P, the Board cD will be rais'd a Foot from the Board IB, and the Water will stand in the Tube at d, because the Cylinder of Water CABID weighing 100 Pound, will press as much downwards as 2 Half-Hundred Weights on CD, when the Boards are just touching. This also shews that the lateral Pressure is according to the Height, as the Water goes in sideways at *pi*; and that the Water pushes in all manner of Directions (as we have shewn) does also appear here, when we make use of the Tube Cc, thro' which the Water having pass'd, swells the Leather, and separates the Boards in the same manner as when it came thro' PpI.

I 18. Tho'

Plate IX

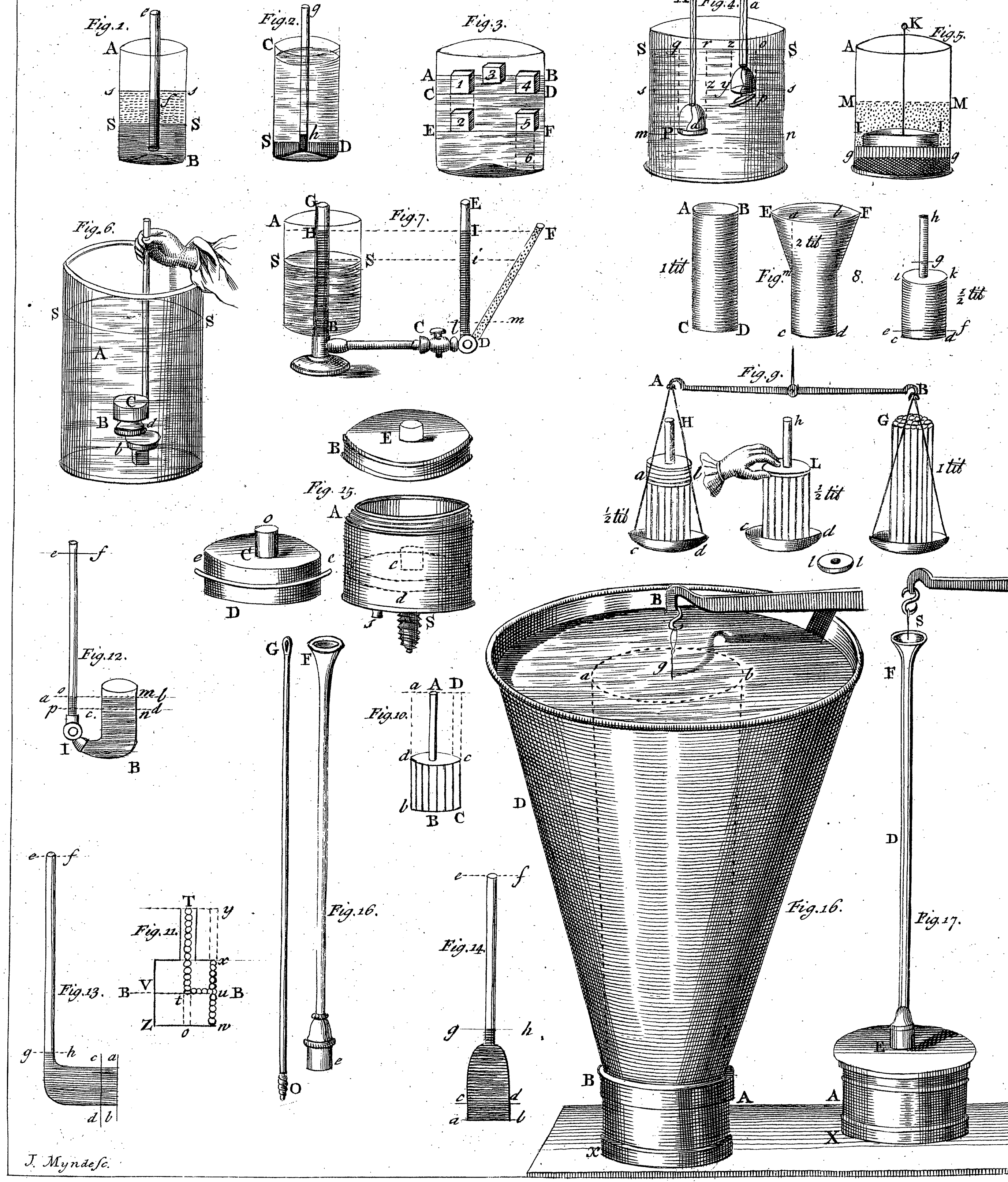


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 16.
Fig. 16.
Fig. 17.
1 lit
2 lit
½ lit
½ lit
½ lit
1 lit
J. Mynde sc.

Lect. VII.

18. Tho' it be very obvious that Water rises to its own Level, yet the ancient *Romans* did not know that Water coming from a great Distance had that Property; otherwise they wou'd not have been at the immense Expence of making Aquæducts, and carrying them from one Mountain to another over Arches built upon one another, as may be seen in several Places: and tho' we often find some of their Clay Pipes for the conveyance of Water, yet none of them are made to rise again after a Declivity. But now that Water-works are better understood, several Towns are very well supplied from Reservoirs at great Distances (some Miles sometimes) distributed to several Houses, and beautifully conducted to make Jets in Gardens. The best way of doing this is what I shall shew in these Lectures in general, but more particularly in the Notes, where I shall give Rules and explain Phænomena not taken notice of hitherto. * * Ann. 7.

Experiment 18. *Plate* 10. *Fig.* 2.

ABCD is a Vessel of Tin or Copper two Foot high, of about 6 Inches Diameter, with a cylindrick Dish at Top of about one Foot Diameter and six Inches deep, to represent a Reservoir of Water; from the Bottom goes an horizontal Pipe of Conduct KI, and from I a vertical Pipe IE, with Ajutage or spouting Holes K, G, H, to open upon occasion. This Vessel being fill'd with Water, the Pipe IE will also be full; so that a Plane passing along the Line EAF, will touch the Surface of the Water in the Pipe and in the Reservoir, so that the Surface of the Water in the Pipe at E, will be neither more nor less press'd than an equal Part of the Surface AF by the incumbent Air. But if you open any of the Jets in the Pipe of Conduct, the Water will not rise up to the Line EF, because the Air does not only press at top, but every way on the spouting Water. If the Hole of the Ajutage be so big that the Pipe of Conduct does not supply fast enough, as at K †, the Water will not rise to its full Height: and if the Hole be too small as at H, the Air will have so much Power over it, as also to hinder its rising to the full Height. But if the spouting Hole be big enough, without being too big to be supplied by the Pipe of Conduct, the Jet will rise to the greatest Height possible, especially if it is not quite perpendicular; because the Water that makes a Head on the top of the Jet, presses it down, and takes somewhat from the perpendicular Height. The loss of Height in Jets, Size of the Pipe of Conduct, and Rules for their Management, shall be shewn in the Notes. ||

Plate 10. Fig. 2.

† Ann. 7.

|| Ann. 7.

When

Lect. VII. WHEN Water in a Town is to be distributed from a Reservoir to several Persons, we ought to know how to measure the Expence of Water; for it is very different tho' it spouts thro' Holes of the same Size, when the Height of Water above the Holes is different: for

18. THE Expence of Water is as the square Roots of the Heights of the Water above the spouting Holes.

EXPERIMENT 19. *Plate* 10. *Fig.* 3.

Plate 10. Fig. 3. THE Machine abovementioned must be also used here, but with a Spout at B to let out the Water coming in from a Pipe at A, that the Vessel may be always kept full. Then having a little spouting Pipe at C, 4 Inches below the Surface of the Water, and another at D, 16 Inches below the said Surface, let those two Spouts run at once in different Vessels (the Reservoir being kept full) and then having stopp'd both the Spouts at once, you will find that the Vessel F has received double the Quantity of the Water in the Vessel E; which proves the Proposition, 2 and 1, being the Roots of 4 and 1.

Plate 10. Fig. 4. 19. To know how far Water, or any Fluid will spout on a Plane plac'd any where below its Surface, according to different Heights of the spouting Holes, you must use this Method. Let the Line AB, *Fig.* 4. represent the Plane on which you would have the Liquor spout. At E raise the Perpendicular BC, equal to the Height of the Surface of the Liquor above the said Plane. On the Line BC describe the Semicircle BDC, and at I, K, L, mark the Place of the spouting Holes below the Surface at C. From I, K, and L, raise Perpendiculars till they come to the Circumference of the Semicircle at E, D, and F. From those Points let fall Perpendiculars to AB, as E*e* and D*d*. Set off B*e* from *e* to G, and B*d* from *d* to H, and the Points G and H will be the Place on the Plane where the Liquor will spout, that is, where the Jets will be intercepted by the Plane. *NB.* The Amplitudes of these Semi-parabola's will be proportional to the Sines IE, KD, LF, consequently that Spout will go farthest which jets out in the Middle of the Height between the Surface of the Liquor and the Plane AD, because the Sine there being an half Diameter is the greatest that it can be. But the Quantity of the Water of these Jets is not as the Distance which they spout to, but as the Velocity of the Water, which is as the Square Roots of the Heights of the Fluid above the Hole, as we have shewn before. This is shewn by an Experiment made with the Machine of Figure 3, kept full; G, H, and I being made the Jets, which will spout to K and L.

TO

To know how to estimate the Pressure of Water upon Sluices, Dams, Banks, or any kind of Surfaces, we must understand the following Lect. VII.

PROPOSITION VIII.

20. *The Pressure of Water upon any Surface under Water, in any Position, is equal to the Weight of a Body of Water, found by multiplying the Area of that Surface, by the Depth of its Centre of Gravity below the Surface of the Water.*

Let ABCD (*Fig.* 6.) represent a Surface, suppose a Wooden Plane 4 Foot long, and 4 Foot wide, that is, containing 16 square Feet. We will first suppose it to lie in an horizontal Situation 4 Foot under Water. In this case it is evident that on every Square Foot of the Plane, there presses a perpendicular Column of Water, containing four cubick Feet; and therefore the whole Pressure on this Plane, is the Weight of a Solid of Water weighing 64 cubick Feet. In this Case K the Center of Gravity of the Plane, is 4 Foot under Water, which Depth multiplied by 16, (the Area of the Plane in square Feet) gives 64 for the Solid above mentioned. If this Plane be plac'd only 2 Foot under Water, each Column of Water bearing perpendicularly on a square Foot of the Plane, will be but 2 Foot long; so that the whole Solid will be but 32 cubick Feet of Water, which is the Product of the Area of the Plane by 2, the Depth of the Center of Gravity below the Surface in this Situation. In this manner may the Proposition be demonstrated for every horizontal Situation of the Plane. Now we will consider the other Situations of the Plane, and first the vertical; but to make the thing easier, we will only suppose the Plane one Foot wide, and four Foot long. Now let the Plane be supposed to stand upright in the Line AB, (*Fig.* 5.) ACDB, 16 cubick Feet of Water bearing against AB; A*k*D a diagonal Line, and *f* the Center of Gravity of the Plane AB: I say, that if a second Plane is plac'd in the Line AD, the Quantity of Water contain'd between those two Planes, will be all the Water pressing against the Plane AB; in this Case 16 cubick Feet. Plate 10. Fig. 6.

Fig. 5. Since the lateral Pressure of Fluids is equal to the perpendicular, the Pressure on all the Points of the Plane AB, as on *a*, *f*, *g* B, *&c.* may be estimated by the Length of the horizontal Lines *a h*, *f i*, *g k*, BD, terminated by the Planes AB and AD, which are equal to the Perpendiculars A*a*, A*f*, A*g*, and AB, as they are Sides of the same Squares. Now all the horizontal Lines between A and *ah*, or rather the thin Plates of Water contain'd between A and *ah*, the upper Foot of the vertical Planes, that is between the Point A and *a h*, make up but half a cubick Foot of Water, which expresses the Weight pressing on Plate 10. Fig. 5.

Lect. VII. A *a*. Thus will the Water *afih*, a cubick Foot and a half, be the Water pressing on the second Foot *af* of the Plane AB: *fikg*, two cubick Feet and a half, be the Water pressing on *fg* the third Foot of the Plane AB; and *gk* DB, three cubick Feet and a half of Water, be the Water pressing on *g* B, the lowest Foot of the Plane AB. Thus the whole Pressure on the Plane AB will be the Water contain'd between AD and AB; as may be better seen in the 6th Figure, where A*ae*E, E*efk*, *kfg*G, and G*gb*B in the pointed Lines, represent the square Feet of the Plane, and where it is to be observed that the Center of Gravity being at *k*, two Foot under the Surface of the Water, the Surface AB (now supposed only one Foot wide) multiplied by that Depth, will produce a Solid represented here by the Section A*ko*C, containing 8 cubick Feet of Water, the same in Contents with the Solid represented by ABD, which we have shewn to be the Weight of the Water pressing on AB.

Plate 10. Fig. 6.

THE Pressure of the Water may thus be found in any Situation of AB; for if the top A remaining in its Place, the Bottom B approaches to or recedes from the Line AD, the Center of Gravity *k* will rise, and so its Depth, by which the Surface AB is to be multiplied, will be less: And if the Bottom B remaining, the top A approaches to, or recedes from the Line AD, the Point *k* will be lower under Water, and consequently the Product of the Multiplication of the Surface AC by a greater Depth of A*k* will be greater.

Plate 10. Fig. 7.

WHILST ABC represents the Water pressing against AB (see *Fig.* 7.) in the Direction *de*, if the Point O be sustain'd against the Force of the Water, either by a Prop behind, or a String running over a Pully, to which hangs a Weight equal to the Weight of the Water ACB, AB will support the Pressure of the whole Water. That Point is call'd the Center of Pressure, and is always two Thirds below the Surface of the Water on the Plane. It is very near of the same Nature as the Center of Oscillation in Solids.

Of the Nature of AIR, *and some of its general Properties.*

AIR has so much to do in several Phænomena of Water, as in Syphons, Pumps and Fountains, *&c.* that I thought proper to consider it in Part here, in order to explain several things in Hydrostaticks, which wou'd require many Words without a previous Knowledge of the general Nature and Operations of Air. As for some particular Properties of it lately discover'd, I shall consider them elsewhere.

DEFI-

DEFINITION.

21. AIR is a Fluid eaſily compreſs'd, which dilates it ſelf again when the Force that compreſs'd it is remov'd. This may be illuſtrated by a Spunge, or a Fleece of Wool. See *Fig.* 8. Plate. 10. Fig. 8.

EXPERIMENT 20. *Plate* 10. *Fig.* 8.

S *s* is a Spunge on the Plane A B. If laying your Hand on it at S, the top of the Spunge, you preſs it down to C D, ſo as to bring it within the Compaſs of C *mns* D, as ſoon as you remove your Hand, the Spunge will reſtore it ſelf to its former Dimenſions. The ſame will happen to a Fleece of Wool. This Property is call'd the *Elaſticity* of the Air.

22. THE Air which encompaſſes the terraqueous Globe, with all the Vapours and Exhalations that are mix'd with it, is called the Atmoſphere *. It is reckon'd to reach to the Height of about ſixty Miles; that is, to be ſenſible to about that Height, becauſe of late Years ſome Meteors (which are ſuſtain'd in it) have been ſeen to riſe to about that Height: Tho' it may be ſtill higher, but of a very ſmall and almoſt inſenſible Denſity. * Annot. 8.

23. WHERE the Surface of the Earth is not ſenſibly heated †, the Atmoſphere is denſeſt next to the Earth, and is thinner gradually as you go up higher and higher, till it becomes many thouſand times thinner or rarer than at the Surface of the Earth. This may be illuſtrated by the Example of the Accumulation of Fleeces of Wool in the following manner. † Ann. 9.

Plate 10. *Fig.* 9.

LET T T be Part of the Surface of the Earth, on which we will ſuppoſe a Tower of a great Height (open at top) to be built; and let I T, K T, repreſent the Sides of that Tower. Suppoſe a certain Quantity of Wool to be put in at the Bottom of the ſaid Tower was to reach up to the Line A B. If the Wool was not compreſſible, an equal Quantity of Wool would reach up to the Line C D, another Quantity equal to that would reach the Line E F, another would reach the Line G H, and a fifth, equal to the reſt, would reach up to the Line I K. But ſince Wool is compreſſible, the Quantity of Wool C B, being laid on the lower Wool A T, will compreſs it, and make its Surface deſcend from A B to *a b*, whilſt C D comes down to *n o*, which the Bottom of the Quantity E D following it muſt come to, whilſt its Surface is brought

Lect. VII. Plate 10. Fig. 9. from E F to *i k*. But as the Wool E D (now *i k n o*) is heavy, it will press down the Surface of C B (now *n o a b*) to *p q*, its own Surface coming down to *l m*; and that of the lowest Quantity A T (now *a b* T T) to *c d*, so as to reduce it into the Space *c* T T *d*, three Fifths of the Space it occupied before. Now let us consider the Effect of the Wool G F. As E F, the Surface of the Wool E D, is now at *l m*, its Bottom will bear on *p q*, the present Surface of C B, which by its Weight it will push down to *r s*, (while its own Surface descends to *x x*) as also make *c d*, the Surface of the lowest Quantity, descend to *e f*, so as to reduce that Quantity into the Space *e* T T *f*, two Fifths of what it occupied at first. Lastly, the Quantity of Wool I H is now come down so low as to be in the Place 9 5 6 9, pressing with its Bottom 5 6 upon the Quantity G F, (now 5 *x x* 6;) and as it is heavy it will cause the Surface *x x* to descend to 10 10, while the Quantity E D (now 10 10 *y z*) will press upon the Quantity C B, (now *y z e f*) which will reduce the first Quantity A T (now *e* T T *f*) into *u* T T *u*, the fifth part of its former Dimensions, as it has five times more Wool pressing upon the Bottom T T. *N. B.* We have not here consider'd that all the Quantities of Wool, except the highest I H, must be condens'd into less Dimensions than they had at first, according to the several Quantities incumbent upon them. Therefore, to avoid the tedious Consideration of every Particular, you may cast your Eye upon the Effect of the Pressure of the several Quantities laid upon one another, as they appear in

Plate 10. Fig. 10. Figure 10, where the several Quantities of Wool A T, C B, E D, G F, I H, are by the Compression of the super-incumbent Wool reduc'd into the Spaces mark'd by the same Letters. This will shew that the Density of the lower Parts is proportionable to the Compression occasion'd by the upper; which are here from the Bottom to the Top, in the proportion of $\frac{1}{5}$, $\frac{2}{5}$, $\frac{3}{5}$, $\frac{4}{5}$, $\frac{5}{5}$. If I H be remov'd, A T will expand itself, and occupy $\frac{1}{5}$ more Space, being rarefied to $\frac{2}{5}$; but if another Quantity, such as I H, be laid upon I H at its Surface I K, the Quantity A T will be compress'd into $\frac{2}{5}$ less Space than it occupied before.

This would be strictly true of Wool, if its Elasticity was perfect; but it is only true in relation to Air, whose Elasticity is perfect when it is

* Ann. 10. pure Air *, whose Condensation and Rarefaction we have endeavour'd to represent by Wool, or Spunges; tho' we don't mean to explain the Make of the Particles of Air by those of Wool, or Spunges, which are made up of little Springs coil'd up, which take up but a small Space, when press'd together; but, when freed from that Pressure, unbend themselves, and take up much more room: because such a Figure will never

reach

reach the prodigious Rarefaction of Air, which, under different Circumstances, is expanded from 1 to 30,000 *. Lect. VII.

* Ann. 10.

Proposition IX.

The Air's Density is strictly equal to its Compression, as appears by the following

Experiment 21. *Plate* 10. *Fig.* 11.

Take a Glass Tube of $\frac{1}{7}$ of an Inch Bore within, 62 Inches long from A to B, besides the Return B C, and one Foot turn'd up parallel to A B at C H, open at top at A, and hermetically seal'd (that is, clos'd with the Glass) at H. Fill the Part B C gently with Quick-silver, so that there may be a Foot of Air at C H. Then pouring in at A Mercury, so as to reach to I, near 31 Inches high, the Air in the Space C H will be reduc'd into the Space H $d\,e$ = 6 Inches, the Mercury in this short Leg rising up to $d\,e$, so as to reduce the Air into half the Space it occupied before; because 30,8 Inches of Mercury in Height press as much as the whole Atmosphere. For when the Air (which, press'd by the Atmosphere, took up the Space of C H = one Foot) came to be press'd by an additional Weight of Mercury equal to the Atmosphere, it must be compress'd into 6 Inches, half the Space, by a double Weight. *Which was to be prov'd.* Plate 10. Fig. 11.

Fill in more Mercury at A, till it rises near 62 Inches high, then the Air will be reduc'd into the Space H $f\,g$, a Third of what it occupied before; as it is now press'd by three times the Weight. But if you incline the Tube so fill'd, till you bring the Surface of the Mercury to be but 31 Inches perpendicular over B, the Air will expand itself again, and descend to $d\,e$, having now only a double Density; because Fluids pressing upon the same Base, act not according to their Quantity, but their perpendicular Height.

24. The Air that we breathe is in a compress'd State, and of the same Density at the same Level, unless where it is accidentally heated or cool'd *: but when that Heat or Cold is remov'd, the Air returns to the same Tenor with the ambient Air. The Air may be likewise condens'd or rarefied by any Power; but when that Power ceases to act, it returns to its former Density.

* Ann. 11.

Proposition X.

The Air in an open Vessel, whether large or small, is able by its Spring to support the whole Weight of the Atmosphere: as the Air in the

Lect. VII. the Veſſel A B *. For if we ſuppoſe that Air weaker than the Atmoſphere, it muſt yield by the Preſſure of the Atmoſphere, and ſink down (for Example) to *e f*, at which time it will have increas'd its Denſity in proportion to its Compreſſion, and conſequently its Elaſticity, whereby it will ſuſtain the incumbent Atmoſphere. Again, if the Air in A B was ſtronger than the Atmoſphere, it could not continue in that State, but expand itſelf, for example, to *g h*, till it became weaker by its Expanſion, ſo as only to ſuſtain the Atmoſphere without lifting it up.

* Plate 11. Fig. 1.

EXPERIMENT 22. *Plate* 11. *Fig.* 2, and 3.

Plate 11. Fig. 2, and 3.

TAKE the hollow Glaſs Ball B, containing about a Pint, with a Braſs Cap and ſmall Hole C; and having ſuck'd out ſome of the Air contain'd in it, ſtop C with your Finger; then take off your Finger near the Candle A, and the Flame of the Candle will be driven to the Hole by the outward Air which runs into the Ball, (whoſe Air is now rarefied) till the Air in the Ball is reduc'd to the ſame Tenor as the outward Air. But if the Air in the Ball be condens'd by blowing into it; when you bring it to the Candle, it will blow the Flame; till by its Expanſion it becomes no denſer than the common ambient Air.

EXPERIMENT 23. *Plate* 11. *Fig.* 4, and 5.

Plate 11. Fig. 4, and 5.

IF, inſtead of the Flame of the Candle, another Fluid, as Water, be interpos'd between the denſer and rarer Air, that Fluid will be driven towards the rarer Air, as long as there remains any Difference of Denſity in the two Quantities of Air. Having ſuck'd ſome Air out of the little Glaſs Fountain F, and having ſuddenly ſtopp'd the upper end of its ſpouting Pipe P*p* with the Finger, invert the Spout under S S, the Surface of the Water in the Veſſel A B. Then immediately upon the Removal of the Finger the Water will run up thro' P, and out at *p*, ſo as to fill up Part of the Fountain. But if you had blown into the Fountain *f*, (*Fig.* 5.) ſtopp'd P, and, having inverted the Spout under the Water *s s*, remov'd the Finger, the condens'd Air in the Fountain would expand itſelf, and come out in Bubbles at P, under the Water contain'd in the Jar *a b*.

EXPERIMENT 24. *Plate* 11. *Fig.* 6.

THE Fountain being ſet upright half full of Water, ſet your Mouth to *s*, and ſuck out ſome of the Water, which will rarefy the Air at *a*, in proportion

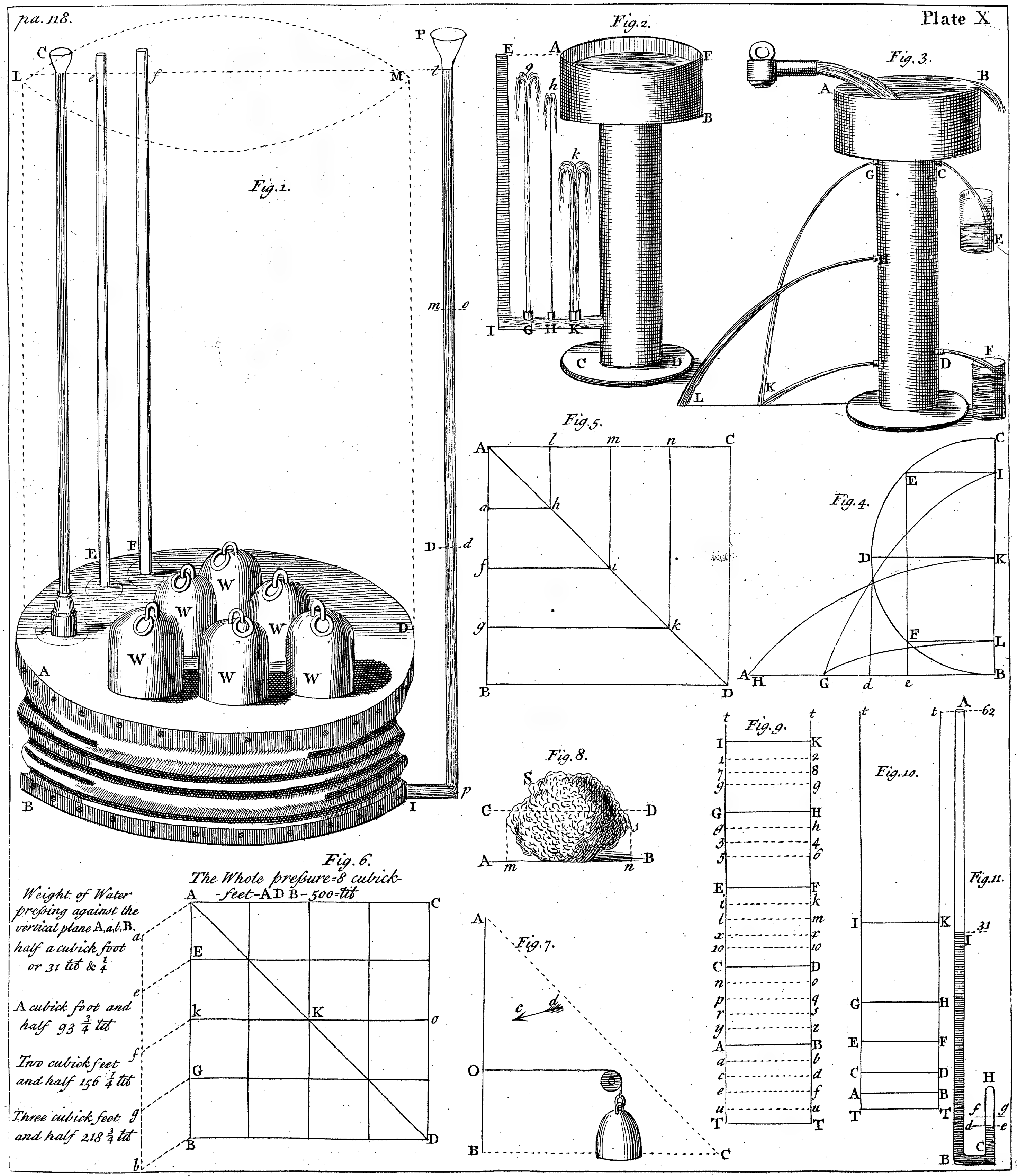


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
The Whole preſsure=8 cubick-feet-ADB-500=lib
Weight of Water preſsing against the vertical plane A,a,b,B.
half a cubick foot or 31 lib & 1/4
A cubick foot and half 93 3/4 lib
Two cubick feet and half 156 1/4 lib
Three cubick feet and half 218 3/4 lib
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
62
31

proportion to the Water ſuck'd out: then the outward Air will ruſh in at S, go thro' the Pipe to the Bottom of the Water in Bubbles, and come up again into the Space *a*, as much in Quantity as there was Water drawn out, till the Air in that Space *a* is become as denſe as the external Air. Lect. VII. Plate 11. Fig. 6, and 7.

EXPERIMENT 25. *Plate* 11. *Fig.* 7.

INSTEAD of ſucking at the ſpouting Pipe S, blow hard into it, ſo as to condenſe the Air in the Space *a*: then immediately that Air by expanding itſelf will preſs upon the Water, and cauſe it to ſpout out at S, as long as the Air in *a* is denſer, and conſequently ſtronger than the external Air, which it will ſoon ceaſe to be by its Expanſion.

PROPOSITION IX.

25. HEAT expands the Air, and Cold condenſes it.

EXPERIMENT 26. *Plate* 11. *Fig.* 8.

INTO the Jar S A C S throw a lighted piece of Paper, and the Air in it will expand, ſo as not to be contain'd in the Jar. For example, what was at the Surface S S will riſe up to *s s*, whilſt the Air in the Space A C B will expand, ſo as to fill up the whole Jar. Invert the Jar ſuddenly before the Fire is out, with its Mouth into the Water of the Veſſel A B C D; and, as ſoon as the Flame is extinguiſh'd, (which was the Power that expanded the Air) the Air in the Jar will return to its former Dimenſions, *viz.* into the Space A C B of *Fig.* 8. The external Air which would ruſh into the Jar now meeting with the Surface of the Water S S in its way, drives it into the Jar up to *s s*, till the Air that had been rarefied by Fire is reduc'd into the Space P *s s*, equal to the Space A B C, (*Fig.* 8.) the Space it occupied before it was heated. If a Spunge full of Water, colder than the Air, be applied to the Jar over P after the Paper is extinguiſh'd, the Water will riſe up to *t t*, the Air in the Space *p t s s* occupying leſs Space than ſo much common Air. Plate 11. Fig. 8, and 9.

PROPOSITION XI.

DENSE Air will drive a yielding Solid into a Space occupied by rarer Air.

EXPERIMENT 27. *Plate* 11. *Fig.* 10.

To a Glaſs Receiver B, of about three or four Inches Diameter, having a Cock and Braſs-Work at C, faſten a piece of wet Bladder *b b*, ſo as Plate 11. Fig. 10.

to

Lect. VII. to cover its Mouth. Then take the Cupping-glass G, and having held it over the Candle A, to rarefy the Air within it, apply it suddenly to the Bladder *b b*, covering the Mouth of B, and the Bladder will rise concave into the Cupping-glass at *g*. This will succeed just in the same manner, whether the Cock C be open or shut *. When it is open, the Pressure of the Atmosphere acting thro' the Cock drives the Bladder into the Air at *g*, which being rarer than common Air, is unable to support the whole Pressure of the Atmosphere. When the Cock is shut, the Bladder rises at *g*, because the Air in B not having been rarefied, but being equal in Density with common Air, drives the Bladder into the Space *g*; less resisting, because rarer, than common Air.

Plate 11. Fig. 10.

* Ann. 12.

Corollary.

26. Hence follows, that Air in any Space acts as strongly by its Spring as the Atmosphere does by its Weight, as we shall shew hereafter.

Experiment 28. *Plate* 11. *Fig.* 11.

Plate 11. Fig. 11.

To the Bottom of the Glass Receiver A B F tie on the Bladder E, open at B F, but close at the little Handle *d*. Then having another small Bladder with its Neck fasten'd to the Tube C D, which has a Screw at S, thrust in that Bladder thro' the Neck S *a* into the Receiver, and screw all fast at S. This Machine represents the Operation of the Lungs in the human Body. The Bladder D, and Pipe D C, are intended to represent the Lungs; for tho' the Lungs are made of several Lobes, and an infinite number of little Bladders not represented here; yet as they all swell and subside by the Air passing in and out at the Wind-pipe, their Motion may well be represented by the swelling and shrinking of the Bladder, and the Wind-pipe by the Glass Tube. The Receiver A B F represents the Cavity of the Chest or *Thorax*, and the Bladder B E F performs the Operation of the Diaphragm or Midriff. The Air between the two Bladders represents the Air contain'd in the Cavity of an Animal's Thorax, which, when condens'd, presses down the Lungs; and, when rarefied, suffers them to rise by the Influx of the external Air thro' the Wind-pipe. *The Operation is thus perform'd.* By the Handle *d* push the Bladder E into the Receiver up to *e*. This will diminish the Cavity A B F, containing the Air in the Thorax without the Lungs, and there, by condensing the Air, render it stronger than the Air in the Lungs, which is of the same Tenor as the outward Air. This will make the Bladder *a b c* (or Lungs) subside, and discharge its Air out

out at C, which represents *blowing*, or Expiration. Pull down the great Bladder or Diaphragm from *e* to E, the Cavity A B F representing the Thorax will be increas'd, consequently its Air will be rarefied; and as it is now weaker than the external Air, the external Air will rush in at C, and swell up the little Bladder or Lungs at *a c b*; and thus will shew the Operation of *sucking*, or Inspiration.

End of the SEVENTH LECTURE.

Annotations upon the Seventh Lecture.

1. [——*Incompreſſible as Water.*]

MANY Ways have been contriv'd to condenſe Water; but no Force has been found ſufficient to do it. The moſt remarkable Experiments have been made with hollow Globes of Metal, which being fill'd with Water, and the Hole ſcrew'd up faſt, have been hammer'd and ſqueez'd in ſtrong Preſſes, to alter them from their ſpherical Figure, that by having the ſame Water contain'd in a Veſſel alter'd from its ſpherical Figure, which would have leſs Capacity than the Sphere, it might appear that the Water was condens'd. But whenever the Shape of the Globe was alter'd, the Water ooz'd thro' the Pores of the Metal, in proportion as it had leſs Room, and ſo could not be condens'd. This ſhew'd alſo, that the Particles of Water were ſmaller than the Pores of Metals: even of Gold; for upon trial the Water paſs'd in a ſort of Dew thro' a Sphere of Gold.

2. [8.——*A Fluid will have an horizontal Poſition.*] This is not ſtrictly true, becauſe the Surface of the Water being Part of the terraqueous Globe, muſt be convex. Thus a Veſſel in a Cellar will contain more Water than the ſame Veſſel at the top of a Mountain; becauſe its Convexity is then a Part of a leſs Sphere than when the ſame Veſſel is carried to the top of the Mountain. But theſe Niceties are of no uſe in Hydroſtaticks, becauſe our Senſes cannot perceive the Difference. There is another thing indeed worth obſerving, which is, that if you fill a clean Glaſs Veſſel, whoſe Top is dry, the Water will be accumulated on the Top, and hold together by the Attraction of Coheſion. The ſmaller the Veſſel, the higher the Water will be heap'd up.

3. [11.——*The Drops of Oil riſe again,* &c.] A Drop of Oil containing leſs Matter under the ſame Bulk than a Drop of Water, and endeavouring to deſcend with the ſame Velocity, has leſs Momentum downwards; therefore every Drop of Water contain'd in the Jar deſcending with more Force than the Drops of Oil, muſt make them riſe up to the Surface.

4. [12.——*Raiſing Water by Pumps.*] See the next Lecture.

5. [15.——*The imaginary Surface would be more preſs'd by the Plate alone, than by any correſpondent Column of Water.*] This will ſhew us a way to make any Metal ſwim, or be ſupported in Water. For when once we know the ſpecifick Gravity of the Metal, if we apply a Plate of the ſaid Metal to the Machine which is to keep the Water from preſſing upon it, and plunge it in Water

Water (holding its upper part fast against the said Machine) as many times its Thickness as it is specifically heavier than Water; we may then let go the String, and it will be sustain'd. If it go deeper, the Metal will be push'd up. Thus a Piece of Gold will swim, when its Surface is 19 $\frac{1}{2}$ times deeper than its Thickness under the Surface of the Water, no Water coming to press above it. A Piece of Silver must be ten times its own Thickness under Water: Copper 9 times: Lead 11 times: Brass 8 times, *&c.* Annotat. Lect. VII.

6. [15.—*As an inclin'd Plane, which takes away from the absolute Gravity of the Body, in proportion to its Inclination.*] An ingenious Gentleman rejected this Proof taken from the Consideration of the inclin'd Plane, (see *Plate* 11. *Fig.* 12.) saying, that the Water which fills the Tube T C D up to A B, presses as much upon the Base C D, as the Water E C D F, which fills the Tube in the oblique Position, not because in the inclin'd Tube it bears upon the inclin'd Part F D, but because the Tube, when inclin'd, holds no more Water than when upright; for (says he) A B C D and E F C D being Cylinders upon the same Base C D, and between the same Parallels A F, C G, must be equal, and consequently contain the same Quantity of Water. Now the Mistake consists in this, that the Cylinders have not equal Bases, tho' made of the same Tube. For when the Tube stands upright in the Position T C D, its Base cut by an horizontal Plane, as C G, is circular; but when the Tube is inclin'd, the Base C D changes to *c d*, and becomes oval, as well as the Section at top E F, and every horizontal Section of the Tube: so that the Part of the Tube inclin'd between the Parallels A F, C D, contains as much more Water than the Part of the Tube at A B and C D, as the oval Base *c d* has a greater Area than the circular Base C D. Because, tho' the Breadth of the Section of the Tube remains the same, its Length is chang'd from C D to *c d*. But the Excess of Water in E F *d c*, is sustain'd on account of the Inclination of the Tube, by whose inferior Semi-cylinder it is supported. Plate 11. Fig. 12.

7. [————*Water-works*, &c. *where I shall give Rules, and explain Phænomena.*] The Conduct of Water in Pipes, especially from distant Places, is worth our Consideration. Therefore we shall here take notice of what Impediments often arise in Practice, and shew how to prevent or remedy those Impediments. The Ancients conducted Water in Pipes only down Hill, as we have before observ'd, but never carried it up again, not knowing that Water would rise to its own Level. But we can conduct Water to very great Distances, and bring it from one Mountain to another in Pipes that go down into the interjacent Valleys, and come up again, provided the Reservoir, or Place into which we bring the Water, be something lower than the Spring or Pond from which it comes, and where our Pipes begin. The Water brought home would indeed shew itself at the same Level, but not run out; and thro' the same Pipes the Quantity of Water given will encrease in proportion as the Receptacle is below the Spring. So that if you have a great deal of Water, and would bring it home into a Place but a little below the Level of the original Spring,

you

Annotat. Lect. VII. you must use very large Pipes; but the same Quantity will be brought home in smaller Pipes, consequently at less Expence, if your Reservoir is much below the original Level. If your Distance be great, the Length of the Pipes will considerably diminish the Quantity of Water brought home, by their Friction, which cannot be prevented, but by having the Pipes bigger, if the Water be in such quantity, and so much wanted, as to make it worth the Expence. I tried an Experiment in the Year 1718, at *Cannons*, (the Seat of his Grace the Duke of *Chandos*) upon a Leaden Pipe, whose inward Diameter was 1 $\frac{5}{8}$ Inch; and found, that at 1400 Yards Distance from the Head of Water that supplied it, it did not give a tenth Part of the Water that it would have given at 30 Yards from the Spring, at the same Depth below the Surface. But the chief Impediment is from Air in the Pipes, by which the Water is said to be Wind-bound, and by that means a Pipe of two or three Inches Bore will sometimes not give more Water than if it was but of one Inch Bore; that is, four times or nine times less. But this Air may be discharg'd, and the Pipes reliev'd, as we shall shew.

Plate 11. *Fig.* 13.

Plate 11, Fig. 13. Let A B C D be the Spring, or Collection of Springs, from which a Pipe is to bring Water to the Delivery at E, suppose a Mile, or half a Mile, from the Spring. Now we will suppose E to be but a little lower than D; for example, four or five Foot. If the Surface of the Water in the Spring comes down to the Mouth of the Pipe at D, or sometimes only near it, there will be a good deal of Air that will run down with the Water into the Pipe; and wherever the Ground rises in the Conduct of the Pipe, this Air will lodge itself in the upper Parts of the Pipe, as *a o m r*, and thereby diminish the Water-way of the Pipe, so as to force the Water to pass between *o* and *n*, a Passage five or six times less (nay, sometimes ten times less) than the Pipe when free. Sometimes, tho' no Air should get into the Mouth at D, yet there will be these Lodgments of Air made at the first running of the Water; for when the Water being come down from D to G rises again to *n*, it runs over the Eminence at *n*, without carrying the Air before it, as it had done as far as *a*; but leaving it in the Space *a o r m*, fills the Pipe again at *r*, and so goes on till the next Eminence, where it runs over the lowest Part of the rising Pipe, leaving a Space of Air at top, which pinches the Water, as at *x*, and then filling the Pipe full again till its next rising, where the Water is again pinch'd by the Air, *&c*.

The way to clear the Pipe (which here we suppose of Lead) of this Air, is thus. Going from D along the Pipe, when you come to the first rising Ground, cause the Pipe to be laid bare at the highest Place, as *m*, and there having driven a ten-penny Nail into the upper side of the Pipe, so as to make an Hole thro' it; while the Nail sticks in, hammer up the Lead all round the Nail with the Pen of the Hammer, so as to make a little Button; then taking out the Nail, the Air will blow out violently, till at last the Water succeeds the Air, and then with a Stroke or two of the Face of the Hammer that Hole will be quite stopp'd up. Doing this at every Eminence of the Pipe, the whole Air will be discharg'd, and the full Quantity of Water will be

be brought home at E; and if the Mouth of the Pipe at D receives no Air by the too great Descent of the Water at A B, the Pipe may give its full Quantity for Years. The way to have the whole Water deliver'd, is to measure it, when the Pipe has been clear'd of Air as above-mention'd; and when by measure the Quantity of Water appears to be deficient, the Pipe must again be clear'd of Air. Annotat. Lect. VII. Plate 11. Fig 13.

If the Spring A B C D be very much higher than the Place of Delivery at E, the Places of Air in the Pipe will not be just at the highest Part of the Pipe, but a little beyond it; because the Water running with more Velocity and Force, drives the lodg'd Air still forward, as may be seen at *o p q*, the Air which otherwise would have been at *s*; and therefore the Nail-hole must be made beyond *s*, between *o* and *q*. If the End E be stopp'd for some time, so that the Water may cease to be in Motion, the Air will go back gradually to the highest part of the Pipe, as appears at *u y w t*, where it may be let out. Suppose that the Water, instead of coming from a Spring, be forc'd up its whole way from a Place much lower by an Engine, as F, and up the Conduit F G, then the Places where the Air is contain'd will be beyond the Top of the Eminences of the Pipes, as at *o p q*; and then it will not be sufficient to prick the Pipe with a Nail; because Air will be continually forc'd in with the Water, and refill those Places in the Pipe from which the Air had been emptied, which often occasions the breaking of the Pipes, or at least gives too small a Quantity of Water, and does damage to the Engine. In such a case the following Contrivance must be used.

Plate 11. *Fig.* 14.

Let A B D be that Part of a Pipe of Conduct (commonly call'd a Main) coming from an Engine, which rises over B. The Water push'd along A D fills the Pipe till it comes to *d*, and then runs to *f*, having its Surface at *d f*, the Air filling the Cavity *d e f*, which Cavity will afterwards change its Place, and go on towards D, the Point *d* going beyond *e*. But this will be prevented thus: Suppose this Main to be pretty large, of 4 Inches Bore, (for example) if it be of Lead; and of 6, 7, 8, or 9 Inches Bore, if it be of Wood. You must have a small Leaden Pipe, which in this case we call a *Rider*, laid over the eminent Part of the Main, as *d e f*, of about 30 Foot in length, communicating with the Main at the top of the Eminence, as at *e*, and 15 Foot nearer the Engine, as *d*, and also 15 Foot beyond the Eminence, as at *f*, with a little Branch and Cock C. Now if you open this Cock when the Engine is working, as the Air is push'd forward it is catch'd at *d*, and discharg'd by the Cock; or if it goes beyond it, is catch'd by the Pipe of Communication at *e*, and also discharg'd. When Water comes out at the Cock you must shut it, and conclude the Main to be full. But after some time, the Cock being left shut, Air will gather in the Eminence of the Main, and lodge beyond *e*. But if you return to the Cock, and open it, the Air will come back to the Cock thro' *f*, and be discharg'd. When Water is by an Engine forc'd up into a Cistern, from which it is to run down again to the Reservoir, where it is wanted, (see *Fig.* 13.) this will also be very necessary, because the Water Plate 11. Fig. 14.

in

Annotat. Lect. VII. in the Ciſtern ſometimes fills up the Mouth of the Main, (or Mouths of the Mains, if the Water is carried to ſeveral Places,) and ſometimes not, whereby a good deal of Air goes down with the Water. We muſt obſerve, that in Leaden or Iron Pipes of Conduct, the Diſcharge of Air is abſolutely neceſſary. In wooden Pipes the Air often paſſes thro' the Wood and eſcapes; but if the Pipes are tight and thoroughly ſoak'd, the Air-Cocks and Riders are very neceſſary: and in the running of Water from a rais'd Ciſtern a Mile or two, ſome Perſon ſhou'd turn the Air-Cocks two or three times a day. *Some Years ago two Friends and my ſelf contriv'd an Invention, which we call'd a* Jack in the Box, *whereby Air-Cocks would open and ſhut of themſelves, by the running of Water and Motion of the Air only.* This Contrivance is deſcrib'd in the *Philoſophical Tranſactions*, Numb. 393.

The City of *Edinburgh* is well ſupplied with Water, which is conducted from a Collection of Springs at *Comeſtoune* near three Miles, in a caſt leaden Pipe of 4 Inches diameter, and ſufficiently thick, *viz.* about half an Inch thick in the loweſt Places, and gradually thinner towards the Springs and towards the Delivery; but thicker at the Delivery than the Springs, becauſe the Delivery upon the *Caſtle-Hill* is conſiderably lower than *Comeſtoune*, which is juſt level with the Cordon of the Half-Moon at the Caſtle. I gave Directions in that Work, and had the pleaſure to ſee every thing ſucceed, which I mention here, becauſe the Diſcharge of Air was made at ſeveral Eminences; and there is a Contrivance for diſcharging the Pipes of it at the Springs and at the Delivery.

Plate 11. *Fig.* 15.

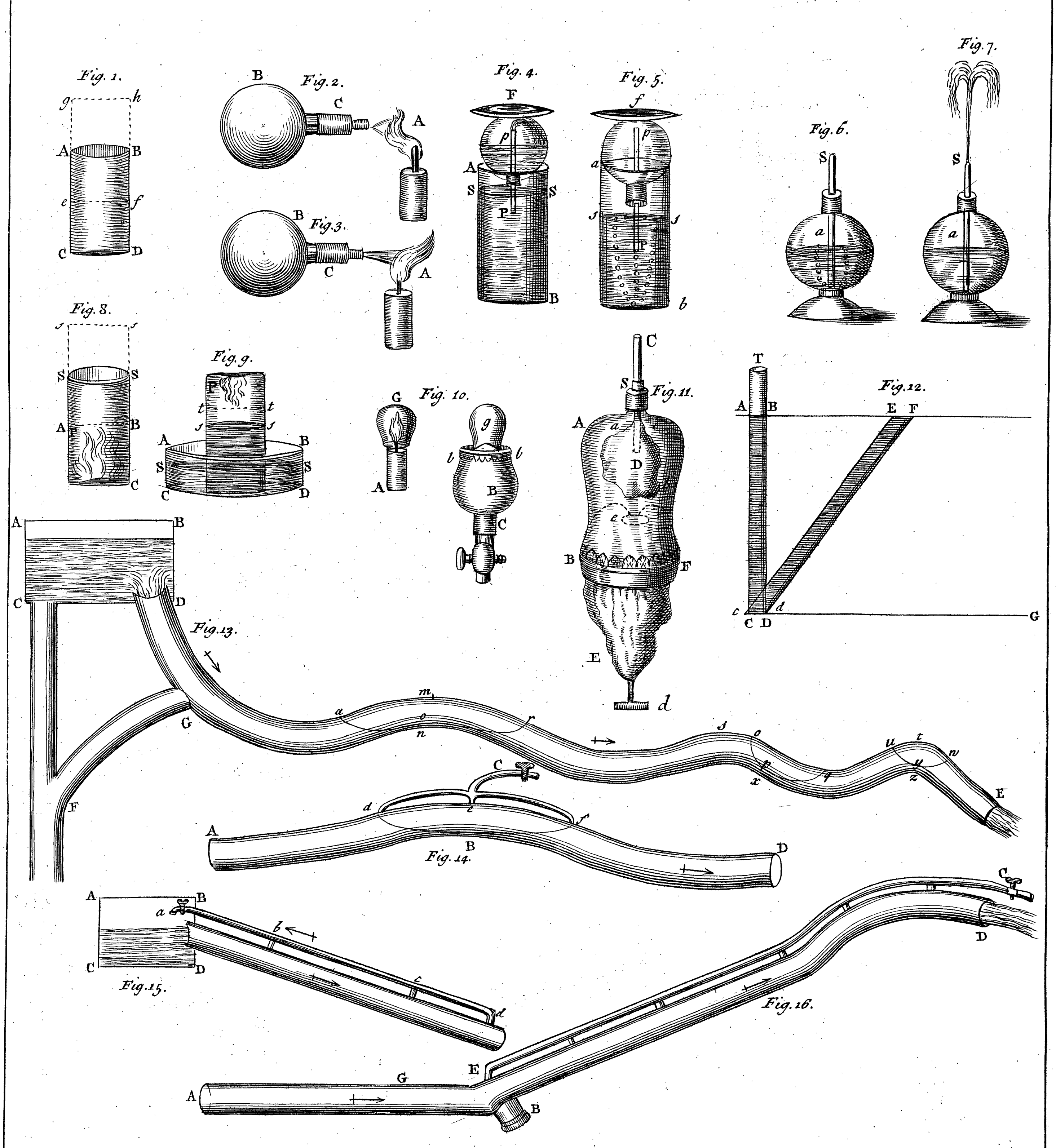
Plate 11. Fig. 15. From the ſmall Reſervoirs at *Comeſtoune*, where the Springs are collected, there is a conſiderable Declivity at firſt, and a *Rider* is fix'd over the Pipe of Conduct to diſcharge the Air at the firſt going in of the Water. A B C D (*Fig.* 15.) is the little Reſervoir, and D is the Mouth of the Pipe into which the Water runs, which is not always wholly cover'd, ſo that Air often goes in with the Water. But the *Rider a*, *b*, *c*, *d*, communicating with the Main at *b*, *c*, *d*, *&c.* brings back the Air in the Direction *d c b* B, contrary to that in which the Water runs down towards *Edinburgh*, as may be ſenſibly felt when the Cock is open, by holding the Hand at *a*. I do not mention the Air-Cocks between *Comeſtoune* and *Edinburgh*, having already deſcribed the manner of them. But there is a long *Rider* from the loweſt Place of the Pipes at the *Graſs-Market*, quite up to the Delivery at the *Caſtle-Hill*, of about 100 Foot in height, and 200 Yards in length, the Uſe of which appear'd by the Experiment we made, which was in the following manner.

Experiment *Plate* 11. *Fig.* 16.

Plate. 11. Fig. 16. We ſuppoſe the *Graſs-Market* at A B, the Water running in the Direction A B D, the Delivery at D, the *Rider* to be E C, and a Plug at B to open at any time for emptying and cleanſing the Pipes. Having ſhut the Cock C, we caus'd the Plug B to be open'd; whereupon all the Water in the Pipe B D, reaching from the *Graſs-Market* to the *Caſtle-Hill*, ran

down

Plate XI.



J. Mynde sc.

down and emptied it self at B. Then the Plug being shut, the Time was taken in which the Water came up to D, which was an Hour and a quarter. After this, the Water being again let out at B, the Cock C was open'd, and the Plug shut; and then the Time of the Water running up from B to C, was but 16 Minutes; the Air which had made the Obstruction before, coming out violently at C. Annotat. Lect. VII.

NB. *What I have said here, and the Example given, may serve to instruct any body in the Conduct of Water from one Place to another, whether by its natural Fall, or driving it at length from an Engine.* There is indeed a particular Case which we should not omit; that is, that the Pipe of Conduct, which carries Water from an Engine directly up into a Reservoir, some Height above it to serve several People with Water, (as the Cistern on the Top of the Tower at *London* Bridge) shou'd not be of Lead, unless extremely thick, so as to be much too expensive, as we shall now explain.

Plate 12. *Fig.* 1.

Let A V D be a Leaden Pipe coming from an Engine below A, where the Water comes up in the Direction A V D, to discharge itself at D. At every Stroke or Push from the Engine, the Water raises the Valve V, and when the Valve shuts again, the Water falling with it, gives a Blow against all the Sides of the Pipe by its lateral Pressure in a Direction perpendicular to the Sides, with the Weight of a Pillar of Water, whose Base is the Section of the Pipe at the Place of the Stroke, and Height the whole Height of the Water above that Place, striking with the same Velocity that the Valve falls. If the first Stroke of this Water makes the Lead swell outwards but the 100th Part of an Inch, the Lead having no Elasticity, will remain in that Position, and not shrink back: Then suppose the next Stroke swells the Lead outwards the 100th Part of an Inch more, the Lead of the Pipe will be a little wider, and remain so: The next Stroke will still make it wider, and so on for many Strokes, till at last the Pipes so widen'd and Lead become so thin, that it must break. And you must consider here, that as after every Stroke the Pipe is wider; as for Example, the Section *c d* is greater than the Section *a b*, and the Section *f e* is greater than the Section *c d*, the Force of the Water striking (which, as we have already said, is equal to the Weight of Water, whose Base is the Section at the Place of the Stroke where the Pipe yields, and Height the Height of the Water above the said Place,) will be greater every time than other, and the sooner burst the Pipe. An Iron Pipe therefore is best to be used, which, tho' it were in it self as weak as the Lead, will not be liable to remain widen'd (tho' each Stroke should make it yield) but return again to its own Dimension after every Stroke. The same will happen in Pipes of Wood, because Wood is elastick. I have seen many swellings of the kind above-mention'd in Conduct-Pipes of Lead, which have been chang'd on that account for Pipes of Wood or Iron; or, if continued of Lead, made much thicker and more costly, than otherwise wou'd have been required. Plate 12. Fig. 1.

Practical

Annotat. Lect. VII.

Practical Rules for Jets d'Eau, *or Spouting Fountains for Gardens.*

NB. I once thought to have given here Monſ. *Marriotte*'s Rules for Jets; but when I conſider'd that my Reader in ſome Caſes muſt be at a great deal of trouble to make his Tables uſeful, by reducing the *French* Meaſures both of Length and Capacity to the *Engliſh*, therefore I have choſen to give Tables calculated from my own Experiments and Obſervations: for tho' upon trying his Experiments, I found moſt of them to anſwer, yet as to the Expence of Water running out of any Veſſel or Receptacle, or ſpouting in a Fountain, I have generally found it leſs than what he gives. But for the Deficiency in the Height of the Jet, from the Height of the Reſervoirs, we exactly agree.

A cubic Foot of River or Pond-Water weighs 62,4996 Pounds Averdupoids; inſtead of which we will reckon $62\frac{1}{2}$ Pounds, becauſe the Water of ſome Springs is heavier than Rain-Water, or River or Pond-Water.

If there be fix'd to a Spring, to the ſide of a Pond fed with Springs, or to the Side-Bank of a River, a Board cut with a ſquare Notch in it, one may by meaſuring the Breadth and Depth of that Notch know what Quantity of Water is given in an Hour from any of thoſe Places, in the following manner.

Having made an Experiment (and often repeated it) of Water running thro' a ſquare Inch Hole, the Surface of the Water being 25 Inches above the Center of the ſaid Hole, and kept to that Height; the Water running out in an Hour appear'd to be 5,2 Tons, or 5 Tons $50\frac{2}{10}$ Gallons. This Experiment (according to the Propoſition N° 18. Experiment 19, of this Lecture) is a Foundation for a Table, ſhowing how much Water will be given thro' a Square vertical Hole of an Inch, from 25 Inches under the Surface. As alſo how much will be given by a ſquare Notch an Inch wide, from 1 Inch to 25 Inches deep; and when the Notch is wider than an Inch, you muſt multiply the Quantity of Water that a Notch of ſuch a Depth in the Table gives, by the Breadth of the Notch in your Board.

NB. If the ſhalloweſt Notch be $1\frac{1}{2}$ Inch deep, we call it but an Inch, becauſe thro' ſuch a Notch (if the Board be 2 Inches thick, as it ſhould be) the Water falls ſo much as it comes over the Board, that at the Edge of it, it is only 1 Inch thick, tho' the Surface of the Water at ſome diſtance, to whoſe Preſſure muſt be attributed the Velocity of the iſſuing Water, is half an Inch above, or 1 Inch above the Center of the Water coming out of the Notch. There muſt be ſo much fall from the Spring, Pond or River, that the Water coming out firſt, may not be a ſtop to that which follows it.

A

A TABLE *of the Expence of Water thro' an Inch square Hole, and thro' a Cut an Inch wide, and of different Depths.*

Inches below the Surface.	Expence of Water thro' an Hole of a Square Inch at different Depths, according to the Number of Inches in the first Column.	Expence of Water thro' a Notch of different Depths, according to the Numbers of Inches in the first Column.
	Tons in an Hour.	
1	1,04	1,04
2	1,46	2,50
3	1,79	4,29
4	2,08	6,37
5	2,31	8,68
6	2,53	11,21
7	2,74	13,95
8	2,92	16,87
9	3,12	19,19
10	3,28	22,47
11	3,44	25,81
12	3,58	29,39
13	3,74	33,13
14	3,88	36,91
15	3,95	40,86
16	4,16	45,02
17	4,28	49,30
18	4,40	53,70
19	4,52	58,22
20	4,62	62,84
21	4,76	67,60
22	4,87	72,47
23	4,94	77,41
24	5,06	82,47
25	5,2 or 5 Tons and 50, 4 Gallons.	87,67

Where the Notch is very wide, as in Cascades, the Water does not fall so much, and therefore one may reckon for every Inch 1 Ton an Hour for a round Number; tho' when the Surface of the Water at the Place where it falls is but $\frac{1}{4}$ of an Inch below the Surface of the Reservoir, the real Quantity is but 0,82 of a Ton in an Hour.

By this means we shall know how much Water we have to supply our Jets; and now we must know what is the Expence of the Water spouted out at our Jets, in order to know how long we can play them, and of what

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Bigneſs to make them. We know by repeated Experiments, that Water coming down perpendicularly out of a Veſſel runs out in a greater Quantity than if it came out horizontally thro' the ſame Hole; and if it ſpouted upwards, the Expence of Water will be ſtill leſs. Therefore in its proper Place we ſhall give a Table uſeful for this Purpoſe. But firſt we'll ſhew the Reaſon why vertical Jets do not riſe ſo high as the Reſervoirs that ſupply them, which is the Reaſon that they give leſs Water than if they went to the full Height.

There are four Cauſes why Jets do not ſpout up quite to the Heights of their Reſervoirs. The firſt Cauſe is, that as all the Particles of Water that form the Column of a Jet ſet out with the ſame Velocity, and that Velocity is continually diminiſhing, the Water that comes after ſtrikes againſt that which goes before, and (becauſe Fluids puſh every way) the Column is widen'd by ſuch an Impulſe, and conſequently ſhorten'd. This would be an Hindrance to the Height, tho' the Jet were to ſpout *in vacuo*. The ſecond Cauſe is, that the Water which is at the Top of the Jet does not immediately run off, but makes a kind of a Ball at the Top of the Jet, whoſe Weight, while it remains there, hinders the Jet from riſing ſo high as it would do. This may be remedied by inclining the Jet a little; for then it will riſe higher, but be leſs beautiful.

The third Cauſe is the Friction againſt the Sides of the Hole of the Ajutage, (or ſpouting Pipe) which will make a ſmall Jet riſe to a leſs Height than a larger from the ſame Reſervoir. This may be remedied by encreaſing the ſpouting Holes in proportion to the Height of the ſpouting Water; provided always, that the Holes are not made too wide for the Pipe of Conduct, but the Rules given in that Caſe are obſerv'd.

The fourth Cauſe, which is the Air's Reſiſtance, cannot be remov'd; but we always know what it is, *viz.* the Air makes a Reſiſtance in proportion to the Square of the Velocity with which the Water of the Jets of different Heights ſtrikes it. Thus if a Jet of five Foot high has loſt one Inch in Height coming from a Reſervoir of five Foot and one Inch high, a Jet produc'd from a Reſervoir of 14 Foot four Inches, will riſe but 10 Foot, loſing four Inches in Height, becauſe as it ſtrikes the Air with a double Velocity, it meets with a Reſiſtance as the Square of that Velocity; that is, four times as great.

Here follow two Tables, the firſt ſhewing by what Heights of Reſervoirs Jets of a determinate Height muſt be produced: and the other ſhews what Jets will be produc'd by Reſervoirs of a determinate Height.

A TABLE *of the different Heights of Jets.*

Height of the Jets. Feet.	*Height of the Reſervoirs.* Feet.	Inches.
5	5	1
10	10	4
15	15	9
20	21	4.

Height of the Jets. Feet.	*Height of the Reservoirs.* Feet.	Inches.
25	27	1
30	33	0
35	39	1
40	45	4
45	51	9
50	58	4
55	65	1
60	72	0
65	79	1
70	86	4
75	93	9
80	101	4
85	109	1
90	117	0
95	125	1
100	133	4

The next is a Table shewing in Feet and Decimals of a Foot to what Heights Jets will rise from an Height of five Feet to 150 Feet.

A TABLE *of the Heights of Jets produc'd by Reservoirs of all Heights between 5 and 150 Feet.*

Height of Ref. in Feet.	Jet Feet and Decimals.	Ref. Feet.	Jets, Feet and 10ths.	Ref. Feet.	Jets, Feet and 10ths.	Ref. Feet.	Jets, Feet and 10ths.	Ref. Feet.	Jets, Feet and 10ths.
5	4,91	26	24,06	47	41,31	68	57,12	89	71,81
6	5,88	27	24,92	48	42,09	69	57,84	90	72,48
7	6,84	28	25,78	49	42,87	70	58,56	91	73,15
8	7,80	29	26,63	50	43,65	71	59,28	92	73,82
9	8,74	30	27,48	51	44,42	72	60	93	74,49
10	9,68	31	28,32	52	45,19	73	60,71	94	75,16
11	10,62	32	29,16	53	45,96	74	61,42	95	75,83
12	11,55	33	30,	54	46,72	75	62,13	96	76,49
13	12,48	34	30,83	55	47,48	76	62,84	97	77,15
14	13,40	35	31,63	56	48,24	77	63,54	98	77,81
15	14,31	36	32,47	57	48,99	78	64,24	99	78,47
16	15,22	37	33,29	58	49,74	79	64,94	100	79,12
17	16,13	38	34,11	59	50,49	80	65,64	110	85,58
18	17,03	39	34,93	60	51,24	81	66,33	120	91,86
19	17,93	40	35,74	61	51,99	82	67,02	130	97,99
20	18,82	41	36,55	62	52,73	83	67,71	140	103,97
21	19,70	42	37,35	63	53,47	84	68,40	150	107,87
22	20,58	43	38,14	64	54,20	85	69,08		
23	21,46	44	38,93	65	54,93	86	69,76		
24	22,33	45	39,75	66	55,66	87	70,47		
25	23,20	46	40,53	67	56,39	88	71,14		

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Height of the Reservoir 8 Foot 4 Inches.

Diameters of the Ajutages in Inches and Parts of an Inch.	Quarts run out in one Minute.
$\frac{1}{8}$	2,5
$\frac{1}{4}$	10
$\frac{1}{2}$	40
$\frac{3}{4}$	90
1	160
$1\frac{1}{2}$	360
2	640

NB. If you would find the Expence of Water from Jets of greater Heights, only encrease the Quantity given here in Proportion to the square Roots of the Heights.

As the Jets do not run out horizontally here, the Quantity of Water is something too great for perpendicular Jets; therefore as the Quantity is to be diminish'd, we may take the Expence of Water, not according to the square Roots of the Heights of the Reservoirs, but according to the Square Roots of the Heights of the Jets. We have therefore calculated the following Table after that manner, shewing in the first Column the Heights of the Reservoirs; in the second Column the Heights of the Jets produced by those Reservoirs; and in the third the Expence of Water in a Minute thro' an Ajutage of $\frac{1}{4}$ Inch in Quarts and Decimals of Quarts.

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A TABLE *of the Expence of Water in one Minute, from Reservoirs of different Heights thro' an Ajutage of a quarter of an Inch Diameter.*

Reservoir's Heights in Feet.	The Height of Jets in Feet and Decimals.	Expence of Water in Quarts and Decimals.
5	4,91	7,7
6	5,88	8,3
7	6,84	9,0
8	7,80	9,6
9	8,74	10,1
10	9,68	10,7
11	10,62	11,2
12	11,55	11,7
13	12,48	12,2
14	13,40	12,68
15	14,31	13,1
16	15,22	13,54
17	16,13	14.
18	17,03	14,26
19	17,93	14,6
20	18,82	15.

Now, since a perpendicular Jet of Water holds more than an upright cylindrick Pipe of a Diameter equal to the Ajutage, and as high as the Jet, it is certain that the Expence of the Water here is something too little: therefore those who wou'd be nice, must take a Mean between the Expence of Water given by this Table, and that given by the last.

In order to bring the Water to our Jets, so that they may play to the utmost Height which they are capable of, we are to consider what Diameter we must give to our Conduct Pipes in proportion to the Ajutage thro' which we are to play our Jet. As for the best way to conduct Water in general, we have already spoken of it.

If we find (as we really do) that a Conduct-Pipe of $1\frac{3}{4}$ Inch Diameter from a Reservoir, whose Height is 5 Foot, supplies a Jet of $\frac{1}{4}$ Inch Ajutage, so that it spouts to its full Height; we are not to imagine that it will supply Water enough to play a Jet from a Reservoir 10 Foot high to make it rise its full Height, tho' thro' the same Ajutage; because as the Water of the Jet rises with more Velocity and in greater Quantity, the Water of the Pipe of Conduct must have Room to follow to supply that Expence of Water fully, otherwise there will be a Friction in the Pipe, which will retard the Supply of the Jet: and much less will it do it, if the Ajutage be of a wider Bore, as it shou'd be in an higher Jet. To set this right, here follows

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A TABLE *of the Diameter of the Pipes of Conduct and the different Ajutages, according to the Height of the Reservoirs.*

Height of the Reservoirs.	Diameter of the Ajutages.	Diameter of the Pipes.
5 Feet	$\frac{1}{4}$ or half an Inch, or $\frac{3}{8}$.	1 Inch and 3 Quarters.
10	$\frac{1}{4}$ or $\frac{1}{2}$ Inch.	2 Inches.
15	Half an Inch.	$2\frac{1}{4}$ Inches.
20	Half an Inch.	$2\frac{1}{2}$ Inches.
25	Half an Inch.	$2\frac{3}{4}$ Inches.
30	Half or $\frac{3}{4}$ of an Inch.	3 Inches, or $3\frac{1}{2}$.
40	$\frac{3}{4}$ of an Inch.	$4\frac{1}{4}$ Inches.
50	$\frac{3}{4}$ of an Inch.	5 Inches.
60	An Inch.	$5\frac{3}{4}$ or 6 Inches.
80	An Inch and Quarter.	$6\frac{1}{2}$ or 7 Inches.
100	An Inch and Quarter, or $1\frac{1}{2}$ Inch.	7 or 8 Inches.

Here we suppose the Reservoir to be pretty near the Jet, as not above 100 or 150 Yards from it; but when the Conduct-Pipe is very long, it must be encreased in Diameter. I have found by Practice the following Proportions to answer very well. For Jets from $\frac{3}{4}$ of an Inch diameter to those of an Inch and a quarter, and from an Height from 40 Foot to about 90, if the Distance be from 150 Yards to a quarter of a Mile, the Pipe of Conduct will do well if it be of 6 Inches Diameter: from a quarter of a Mile to 2 Miles, it must be of 7 Inches Diameter: and from 2 Miles to 5 Miles, the Pipe must be of 8 Inches Diameter for the same Jets.

If you would keep 6 Jets of $\frac{3}{4}$ of an Inch constantly playing, having Water enough to do it, you must consider what wou'd be the Diameter of an Ajutage giving as much Water as all the 6. Multiply 9 Quarters Square of $\frac{3}{4}$ by Six, which will give you 54, of which the square Root is 7,3 quarters, or near 1 Inch and $\frac{7}{8}$ for the Diameter of an Ajutage of equal Contents with the six Ajutages of $\frac{3}{4}$ of an Inch each. Then take for your Conduct a Pipe of 7 times the Diameter of the Ajutage, which will be of 13 Inches, wherewith you must bring down the Water from your Reservoir: Then when you come to divide it into the six Pipes leading to the several Jets, let those Pipes be each of 6 Inches Diameter, the better to avoid the Friction, tho' six Pipes of 5 Inches and a quarter wou'd carry all the Water brought down by a 13 Inch Pipe. Such a Pipe as this shou'd most properly be made of cast Iron in lengths of 12 or 15 Foot, with Flanches to be screw'd together with Lead between. The thickness of these Pipes need not be above $\frac{3}{4}$ of an Inch in the thinnest Place for even 150 Foot in depth; but the Founders will hardly cast them under an Inch thick. Those Persons who have large Elm-Timber upon their Estates may make use of that, using two Conduct Pipes of $9\frac{1}{4}$ Inches Bore, instead of the 13 Inch Pipe, to which they will be equivalent. Lead

would

would be too expensive, as it wou'd require a great Thickness for the Reasons given above. Annotat. Lect. VII.

In using Elm Pipes you must always take care that they be bor'd in the Heart of the Wood, and that the Heart be of sufficient Thickness about the Bore of the Pipe. As for example, the Pipes that lie from 80 to 140 Feet under the Surface of the Water in the Reservoir, must have the Heart of Elm three Inches thick after it is bor'd; for which sort of Pipe a Tree must be made use of, no less than 18 Inches thick in the smallest Part: for a Depth from 60 to 80 Feet, the Heart must be 2 $\frac{1}{2}$ Inches thick, which a Tree of 17 Inches Diameter will supply: for a Depth from 30 to 60 Feet, the Heart must be 2 Inches thick, which a Tree of 16 Inches Diameter will supply: and for any Height under 30 Feet, the Heart need be but 1 $\frac{1}{2}$ Inch thick, for which a Tree of 14 Inches will suffice. From these Proportions you may know how thick the Heart of Elm should be for Pipes of less Bore at the same Depth, taking it thinner in proportion to the Squares of the Diameters of the Bores, the Reason of which will be shewn. Thus a Pipe of 4 $\frac{1}{2}$ Inches Bore at a Depth of 100 Feet, need have the Heart but $\frac{3}{4}$ of an Inch thick; because, as 81, the Square of 9: is to 20 $\frac{1}{4}$ the Square of a Bore of 4 $\frac{1}{2}$: : so is three Inches: to $\frac{3}{4}$ of an Inch. Elm Pipes, such as I have describ'd, will last 20 or 30 Years. When the Water is brought to the Bason, where the Jet is to play, the Pipes must be of Lead, that there may be no occasion for taking them up again upon any Accident. There are cast Pipes of Lead; and Pipes turn'd up of tough Lead, and burn'd together in the Seam long-wise, and also burn'd together with Lead in the Joints as they are laid in the Field, instead of soldering, which is much cheaper. Leaden Pipes may be turn'd up of any Bigness; but I have not known Pipes cast of more than 4 Inches Bore: but unless the cast Pipes are very sound, they are much worse than turn'd up Pipes. I would not advise the using of cast Pipes of more than 2 $\frac{1}{2}$ Inches Bore; but there must be a good deal of Care taken in making the turn'd up Pipes, that they may be very round. The Thickness of Leaden Pipes is as follows: A seven Inch Pipe from 140 to 80 Feet below the Reservoir, must be $\frac{3}{4}$ of an Inch thick; from 80 to 60 Feet, half an Inch and half a quarter thick; from 60 to 30 Feet, half an Inch thick; and from 30 to the Reservoir, $\frac{3}{8}$ of an Inch. For Pipes of 4 Inches Diameter, half an Inch will do from a Depth of 200 Feet to 100; from 100 to 40 Feet Depth, $\frac{3}{8}$ of an Inch; and from 40 to the Reservoir, $\frac{1}{4}$ of an Inch in Thickness. All the Thicknesses here given are sufficient, as having been tried; but if any Person would exactly know what Height of Water a Pipe of any Bore and Thickness will sustain without bursting, it may be try'd in the following manner.

Plate 12. *Fig.* 2.

Take a Piece two or three Feet in length of the Pipe whose Strength you would know; as, for example, the Pipe A B C, bent up at B, above the Level of A C, and turn'd up at each End, as A and C. At the End A let there be a Brass Screw solder'd, that the Syringe or Forcer S may be screw'd to it, so as to

Annotat. Lect. VII. to draw out Water from the Veſſel V to force it into the Pipe. At the End C muſt be cemented on a conick Braſs Valve D, whoſe lower End muſt be juſt an Inch Diameter, and from whoſe upper Part the Wire or Shank D E muſt riſe perpendicularly to receive the Weights *f*, *g*, *h*, *i*, *k*, *&c.* to be put on upon the Valve. Then force in Water into the Pipe, and as the Weights are lifted off of the Valve, lay on more till the Pipe burſts, which it will do at B, the Place where the Air is condens'd, if it be no thicker in that Part than the reſt of the Pipe. To find by the Weights on the Valve, what Height of Water the Pipe will bear, you muſt conſider what follows.

Thirty-six cylindrick Inches, or the Water contain'd in an upright Pipe of an Inch Diameter, and one Yard high, muſt be reckon'd 1 ℔. Weight Averdupoids; becauſe tho' Rain-water is between a 40th and a 50th Part lighter, we may well allow that Difference for the Impregnation of Water from Minerals, or its Foulneſs upon many accounts. If the Pipe be but an Inch Diameter, one Pound muſt be reckon'd for every Yard in Height; but if the Bore be greater, the Square of the Diameter of the Pipe muſt be multiplied by as many Pounds as there are Yards in the Height requir'd. Thus if a Pipe be ſix Inches in Diameter, and 30 Feet in Height; ſquare the Diameter, which is 36, and multiply that Number by 10, the Yards in Height, and you will have 360 Pounds for the Weight of the Water in the Pipe, by which it endeavours to break at Bottom. In the Experiment therefore if the Valve bears but 9 ℔. (for example) before it breaks, you muſt not think that an Height of Water of nine Yards would break it, unleſs the Pipe was but an Inch in Diameter: but if it be of a bigger Bore, as, for example, of three Inches, you muſt multiply the Square of that Number by nine, which will give you 81, the Number of Yards in Height requir'd for the Water to break ſuch a Pipe. Then you muſt take a Quarter from that Number, to know what Height of Water the Pipe will ſuſtain in Practice without Danger, which will be 60 Yards.

In the loweſt place of the Pipe of Conduct there ſhould be a Plug to drive out, or a Cock, whoſe Water-way muſt be equal to that of the Pipe, to let out the whole Water upon occaſion, in order to cleanſe the Pipes. All the Cocks in the Pipe of Conduct muſt have their Water-way equal to the Pipe, otherwiſe they'll check the Jets, and therefore the Pipes muſt be made wider where the Cocks are put in, in order to receive the Shank of the Cocks.

If by often playing your Jets the Water in the Reſervoir comes down within a Foot of, or nearer to, the Mouth of the deſcending Pipe, the Water will make a Funnel, whoſe Inſide is only Air, and not go out in ſufficient Quantity; therefore in thoſe Caſes the Pipe muſt be made like a Funnel opening two or three times wider at the Mouth, and not come to its true Bore, till it has deſcended two or three Feet. There is indeed a Caſe, where we may make uſe of a Cock, whoſe Bore is a great deal leſs than that of the Pipe of Conduct, without any Prejudice to the Supply from the Reſervoir, (that is, without any Diminution of its Quantity) and that is, when the Jets ſupplied by the Reſervoir open much below, and at a great Diſtance from it; provided this Cock be but a little below the Bottom of the Reſervoir. The Reaſon of this

this we ſhall ſhew, when we ſpeak of Water running out from the Bottom of Veſſels. In the mean time this Conſideration may be very uſeful in Practice, eſpecially where the Pipe or Pipes of Conduct are very large, as of ſeven, eight, or nine Inches Diameter; in which a Braſs Cock of the Diameter of the Pipes might coſt 50 or 60 Pounds: whereas a Cock of a much leſs Diameter not coſting above 10 or 12 Pounds, will give all the Water that the Jets will require, or a long Pipe of Conduct will ſupply. But ſuch Cocks muſt not be uſed in the lower Parts of the Conduct, or near the Jets, as I have already hinted, nor muſt the Conduct have angular Elbows, or be contracted any where into a ſmaller Bore. Annotat. Lect. VII.

Tho' the Water is retarded in paſſing thro' a ſmaller Bore, one would not imagine that it ſhould be retarded in paſſing thro' a larger Bore; but yet it is true. It is indeed certain, and it may be deduc'd from what we have demonſtrated, that every Section of a Pipe of Conduct is equally preſs'd by the Column of Water above it, be the Pipe containing that Column of Water wide or narrow, or of any Shape whatever; but then this is only true, when the whole Water is at reſt.

In the running of the Water, where the Conduct is larger than any where elſe, it is plain that that larger Part contains in itſelf a Cylinder or Pipe leſs than itſelf, and of the Bore of the reſt of the Conduct; and therefore that the Water will run as eaſily at leaſt, if not more eaſily, thro' a Pipe made of Water, as thro' a Pipe of the ſame Bore, made of Wood, Iron, Copper or Lead, *&c.* and that there muſt be no more Friction to hinder the running Water, (nay leſs) than if the containing Water was frozen. There would indeed be no more Friction in a Pipe of Ice, than in one of Wood, or Iron, *&c.* ——But when the containing Water is not frozen, it makes a Retardation in proportion to its Quantity; becauſe it muſt be put into Motion by the Water that comes thro' it, as long as it remains fluid.

Just by the Ajutage where the Pipes of Conduct turn up, they muſt not riſe at right Angles, as at *b d* in the third Figure of *Plate* 12. but bend up in a Curve, as at B, C, *Fig.* 4. and tho' we are not to diminiſh the Diameter of the Pipe of Conduct, as ſome ignorant Plumbers do, but carry it on to the Ajutage; yet in very high and large Jets, we may within a few Inches of the Ajutage narrow it by Steps, as at B, F, C, D, E, in Fig. 5. to break off the impetuous Blow that the Water will give at the Beginning of the Play of the Jet. Plate 12. Fig. 3, 4, 5.

For our Ajutages, we muſt not uſe cylindrick or conick ſpouting Pipes, ſuch as are uſed, and are neceſſary, in Engines to put out accidental Fires; but the Water muſt ſpout thro' a ſmooth Hole in a Plate on the Top of the Cap which we put on at the riſing End of the Pipe of Conduct. This Plate need not be above $\frac{1}{20}$ of an Inch thick for a Jet not exceeding 20 Feet in Height: $\frac{1}{10}$ of an Inch from 20 to 35 Feet; from 35 to 50 Feet, $\frac{2}{10}$ of an Inch; from 50 to 65, $\frac{4}{10}$; from 65 to 80, $\frac{6}{10}$; and from 80 to 150, $\frac{8}{10}$; that is, a ſhort cylindrick Pipe under an Inch in length will be ſufficient. *N. B.* Here we ſuppoſe the Pipe of Conduct not to exceed five Inches in Diameter; but if it be more,

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If at any time we want to encrease the Bigness of our Jets, upon which account we must enlarge our Pipes of Conduct, or to have them play from an higher Reservoir, or both; we must consider in what Proportion to encrease the Thickness of our Pipes, especially if they be of Metal, for example, of Lead. If we double the Diameter of the Pipe, we must double the Thickness of the Lead, to enable it to bear the quadruple Pressure which the Water will then give. We must also double the Thickness for double the Height: and for double the Height, and double the Diameter, must quadruple the Thickness.

Besides all this, the Pipes must be laid so deep in the Ground, as to be out of the reach of Frost in Winter: and if that can't be done, every hard Frost the Water must be all let out of the Pipes by the opening at the lowest Place.

Before you make the several Caps to screw on to the End of the Conduct Pipe for your Ajutages, you may try the Beauty of Jets of different Bores, thro' different Thicknesses of Plates, by the following Machine, which I contriv'd for that Purpose.

Plate 12. *Fig.* 6.

Plate 12. Fig. 6, 7, 8, 9. The Machine A B C D, consists of a Brass Plate A D three Inches square, and near $\frac{1}{4}$ of an Inch thick, with an Hole of an Inch and $\frac{1}{4}$ in its Middle at E, and a female Screw under, to screw it fast to the End of the Conduct Pipe. At two of the Ends of this Plate is a square Gibbet of Brass, G B and H C, thro' the Top of which comes down a Screw at S, lifting up, or depressing, a narrow Brass Plate, (such as is represented by *Fig.* 7.) riveted to its Bottom at P, so as to pinch, and hold fast any thing under it. Then another Brass Plate, as R R, (*Fig.* 8.) six Inches long, two Inches wide, and $\frac{1}{20}$ of an Inch thick, with three or four smooth Holes in it, one of one Inch, another of $\frac{1}{2}$ an Inch, and a third of $\frac{1}{4}$ of an Inch Diameter, *&c.* is to be slipp'd in under P and P, so that one of its Holes may lie over the Hole E: then pressing it down tight by means of the Screws S S, you may let your Jets play successively thro' any of the Holes, to see which Jet you like best; and make your Ajutage Caps accordingly. *N. B.* You may have several of these Plates, of different Thicknesses, and different Sizes of Holes, with a Leather under each of them. The ninth Figure represents this Machine seen endwise.

If we compare the Tables of Page 130, and 131, shewing how much the Heights of Jets fall short of the Heights of Reservoirs, with Experiments made with the Machine of Plate 10. Fig. 3. whose Height is about two Foot, we shall find the Height of the Jets made by this Machine to fall very short of the Height proportionable to the Heights in the Table; but the only Reason of this Difference is the Smallness of the Ajutage; for if the Diameter of it be less than the Diameter of a Drop of Water, the Attraction of Cohesion, which is able to hold Water together to the Bigness of a Drop, will extend itself

cross

crofs the Hole, fo as to act ftrongly againft the Force which is pufhing the Water upwards, and thereby diminifh the Height of the Jet. For when it is $\frac{1}{4}$ of an Inch Diameter, (and a Drop of Water is under $\frac{2}{10}$ of an Inch in Diameter) then the Jet will only be hinder'd by the Friction of the Sides of the Hole, and rife to the Height mention'd in the Table. Therefore in all Jets, whofe Diameter is under $\frac{2}{10}$ of an Inch, we muft expect the Height to be much diminifh'd upon this account.

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One may fatisfy one's felf of the Truth of the Tables of the Expence of Water, Page 129, and Page 133, with a fmall Quantity of Water, by the following Experiment, which I found to agree with thofe made upon greater Quantities in Ponds and Rivers.

Plate 12. *Fig.* 10.

A C G is a Tin Veffel two Feet long, 10 Inches wide, and 13 Inches deep, with a long fquare Hole in its Side L, one Inch deep, and three Inches long, whofe Bottom is one Inch and an half below the upper Edge of the Veffel. Oppofite to this Hole is fix'd an horizontal Plate, about three Inches fquare, at P. In the fore-part there is an Hole two Inches fquare at H, whofe Top is level with the Bottom of the Hole L. In the Infide of the Front C H, behind H, are two Grooves not feen here, for a Brafs Plate to flide in with an Hole of any Size, to reduce the Opening at H to what you will. Nine Tenths of an Inch below the Top of the fquare Hole at H, is drawn on the outfide the Line F G, to direct one to place the Center of the Hole of the fliding Plate always at the fame Level, and $\frac{9}{10}$ of an Inch below the Plate, at which the Surface of the Water will always be in the Experiment. I is a fquare Veffel to receive the Water expended, and B is a Barrel, or any Veffel big enough to fupply it, at leaft for a Minute. D E is a perpendicular Plate going down within four Inches of the Bottom of the Veffel, to hinder the Water coming out at B from making Waves towards P, but with many Holes in it, not to check the coming of the Water forward. Having flid in a Plate behind H, with a round Hole of an Inch Diameter, and brought its Center to the Line F G, make the Edges of this Plate tight with a Cement of Turpentine and Bees-Wax, that the Water may only come out at the Hole. Then whilft you hold your Hand againft the Hole at H to ftop it, let fomebody fill the Veffel up to the lower Part of the Hole L, at which time the Water will juft wet the upper Part of the Plate P, which fhews the true Height of the Surface of the Water, (becaufe on the Sides of a Veffel the Water rifes higher than its true Surface.) Then unftop the Hole H juft in the fame Inftant as another Perfon unftops the Hole at B, while a third takes the Time of the Water running into the Veffel I, which muft be fuddenly remov'd at the End of one Minute, and you will find in it juft 13 Quarts, which an Inch round Hole, whofe Center is $\frac{9}{10}$ of an Inch under the Surface, has afforded; which is at the rate of one Ton an Hour. If you make ufe of a Plate with an Hole of half an Inch Diameter, the Water running out will be three Quarts, and $\frac{1}{2}$ a Pint in a Minute, according to the Square of the Diameter of the Hole. If you make ufe of a Plate with an Hole of $\frac{1}{4}$ of an Inch, the Quantity of Water

Plate 12. Fig. 10.

Annotat. Lect. VII expended should, according to the above-mention'd Proportions, be 1 Pint and $\frac{5}{8}$ in a Minute; but it will hardly be 1 Pint and $\frac{1}{2}$, because the Friction is proportionably greater in small Holes than great ones, in regard to the Quantity of Water; this last being as the Squares of the Diameters, whilst that is as the Circumferences, or as the Diameters of the Holes. Here Care must be taken to have the Center of each Hole in the same Line F G; for if we should place the smaller Holes with their Tops at the same Height as the Top of the great Hole, we should have still less Water from small Holes, not only in proportion as the Squares of the Diameters are less, but also in proportion as the square Roots of the Height of the Surface of the Water above the Centers of the Holes are less; besides the Friction already taken notice of.
Plate 12. Fig. 11. Thus in *Fig.* 11. if you consider the Top of the three Holes B, D, F, of an Inch, $\frac{1}{2}$ an Inch, and $\frac{1}{4}$ of an Inch in the Line L L, the Holes D, and F, will lose of the Quantity of Water they should give according to the Squares of their Diameters, in proportion as the square Roots of the Heights C D and E F are less than the square Root of the Height A B. A B = 0,9 Inch, C D = 0,65 Inch, E F = 0,525 Inch: their Roots are 3; 2,54, and 2,29: Therefore as 3 : is to 2,54 : : so is 6 $\frac{1}{2}$ Pints: (the Water that D would give, if its Center was as low as B) to the Quantity it will give, when its Height is only C D: That is, 5,3 Pints, (diminishing still more upon account of a greater Friction) five Pints and a quarter. Thus also will the Hole F, instead of one Pint and $\frac{5}{8}$, give but one Pint and $\frac{1}{4}$.

Again; if we make the Experiment with a large and a small Hole, (as with an Inch Hole, and one of $\frac{1}{4}$ Inch Diameter) with their Center only $\frac{6}{10}$ of an Inch below the Surface of the Water, see *Fig.* 12; then the great Hole will give less Water than in proportion to the Square of its Diameter; because the Surface of the Water over the great Hole will fall near $\frac{1}{10}$ of an Inch, on account of the great Waste thro' such an Hole, whilst the Water over the little Hole keeps its Height, without any sensible Diminution: and this does the same as if the Center of the great Hole was only $\frac{5}{10}$ of an Inch under the Surface, whilst the Center of the little Hole is still six Inches below it.

Plate 12. Fig. 12.

I forgot to give a necessary Caution relating to the Basons in which the Jets play; which is, that we must always have it in our power to clean the End of the Pipe of Conduct from any Foulness that might disturb the Jet.
Plate 12. Fig. 13. If the Bason, as A B C D, *Fig.* 13. be pav'd with Brick or Stone, and the Conduct Pipe, as E F G, be brought on upon the Bottom, just at the lowest Part of the Bend, there must be the short horizontal Pipe F H, to be open'd at any time at H, in order to cleanse the Pipe F E from any thing that should come into it accidentally. But if the Bason be not pav'd, (as is the case in great Basons) and the Pipe of Conduct coming below E M, the Level of the Ground, runs under the Bottom of the Bason, as at I K; besides the spouting End that turns up to K G, the Pipe of Conduct must be continued horizontally to the farther Side of the Bason at L, where it must end in a Pit, as L M, where it may at any time be open'd and cleans'd.

When

WHEN Water is brought into a Reſervoir, either by an Engine, or from Springs, to ſupply the ſeveral Inhabitants with Water; that every Tenant may have a Quantity of Water in proportion to what he pays for it, it is neceſſary the Water ſhould be ſo exactly diſtributed, that each ſhould have what he agrees for; or that if there ſhould be a general want of Water, each one ſhould loſe in proportion to the Quantity that belongs to him. To perform this exactly, there muſt be made a Gauge-Veſſel ſquare, (for example, four Feet ſquare) and about one Foot deep, ſupplied from the Reſervoir with a Pipe, having a Cock with a floating Ball fitted to the Leaver that moves the Key of the Cock, ſo that it may ſhut of itſelf when the Gauge is full, and open of itſelf to ſupply it when there is a want, that there be no Waſte of Water at any time. In the fore-part of this Gauge-Veſſel muſt be fix'd Plates of Braſs with ſquare Holes in them, each Hole one Inch deep, but of different Breadths, according to the Water that each is to ſupply. They muſt not be too near one another, (at leaſt ſix Inches from each other) that the Efflux at the greater Holes may not hinder the ſmaller Holes from giving their full Quantity. The Surface of the Water, when there is no Deficiency, will always be kept at the ſame Level, which muſt be $\frac{4}{10}$ of an Inch above the Top of the Holes: then the Hole, whoſe Breadth as well as Depth is an Inch, will give one Ton *per* Hour; that of half an Inch in Breadth, (the Depth always remaining the ſame) half a Ton; that of $\frac{1}{4}$ of an Inch in Breadth, $\frac{1}{4}$ of a Ton, *&c.* ſee *Fig.* 14. Now if the Springs, or the Engine, do not ſupply Water enough to the Reſervoir to keep up the Water to the Height determin'd above the Holes, each Hole will give leſs in proportion to that Deficiency of Height, which would not happen were the Holes round, for which reaſon ſquare Holes are preferable. If a Tenant, as, for example, a Brewer, who uſes much Water, takes the whole Quantity afforded by an Inch Hole, that is, 48 Hogſheads in 12 Hours, he muſt receive it in a Pipe of at leaſt two Inches Diameter; and there muſt be fix'd to the Gauge-Veſſel, at the Circle C D, a taper Pipe, ſuch as *c d*, to deliver all the Water coming thro' the ſquare Inch Hole into the Pipe or Main that is to convey it away. The ſame may be done proportionably for the other ſquare Holes. If the Water coming out at an Inch Hole be too much for one Perſon, the Spout *c d* may have three ſmall Ends to be ſtopp'd with Cocks, open'd alternately into three Mains, ſerving each of them four Hours ſucceſſively. It would be tedious to be more particular, or to ſay that when Tenants are leſs exact in their Quantity of Water, one Main ſupply'd by one ſquare Hole, with ſmall Branch Pipes upon it, might ſerve a whole Street.

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Plate 12. Fig. 14.

8. [21.——*the Atmoſphere.*] The Atmoſphere is made up of an Infinity of different Particles, ſome elaſtick and ſome not elaſtick, others ſulphureous, ſaline, watery, terreſtrial, which all ſwim in this Fluid in great plenty, and will never become Particles of permanent elaſtick Air. Elaſtick Air conſiſts of Parts endow'd with a repellent Force in reſpect of each other, and which do not touch one another *, (as long as the Air remains in its elaſtick State) whereby

* *When we come to ſpeak of the Reſiſtance of Fluids, we ſhall mention the Experiments whereby we find that the Particles of Air do not touch one another.*

Annotat. Lect. VII. whereby they form a Fluid of perfect Elasticity. This Fluid is also very electrical *, and is the Vehicle of Sound, which moves in it the more freely the more unmix'd the Air is.

* See the Dissertation about Electricity at the End of L. X.

9. [22.——*Surface of the Earth is not sensibly heated.*] In Summer-time when the Ground is heated, the Air is rarefied by that Heat, so as to lift up the Air above it by expanding it self, which it does in proportion to the Nature of the Soil, as it is apt to reflect the Heat which it receives from the Rays of the Sun to a greater or a less Height: and then the coldest Region of the Air will not be next to the Ground as it is in Winter, but at some height above, as we find it is upon the top of Mountains; and thereabouts, (or a little lower) will the Air be densest. So that if the 14th *Fig.* of *Plate* 12. represents the Section of a Column of Air in Winter, whose several Parts 1, 2, 3, 4, 5, 6, *&c.* are equal in Contents, but uneqal in Bulk and Density; the 15th Figure will represent the same Column of Air in Summer, when the Part 1 dilated by Heat, will lift up all the other Parts above it, and then the densest Part of the Column which was before at the Bottom under 1, will now be betwixt 1 and 2. Hence it follows, that if the Barometer stands at the same Height at any time in Summer as it did in Winter, the Column of Air which contains the same quantity of that Fluid, must be higher in Summer than Winter: And it is confirmed by the following Observation. When it is settled fair Weather in *June* and *July*, the Quicksilver in the Barometer always falls a little at 10, 11, or 12 at Night, but rises again about 3 or 4 or 5 in the Morning; because when the superiour Air has been lifted up by the Expansion of the heated Air below, it spreads and falls off every way, which diminishes the quantity of Air in the perpendicular Column pressing on the Mercury in the Barometer; but when the Ground cools, the Air below condenses again, and the superiour Air falling makes a kind of Pit at Top of the Atmosphere, which being fill'd by the adjacent Air, increases the Column, and makes the Mercury rise again.

Plate 12. Fig. 14, and 15.

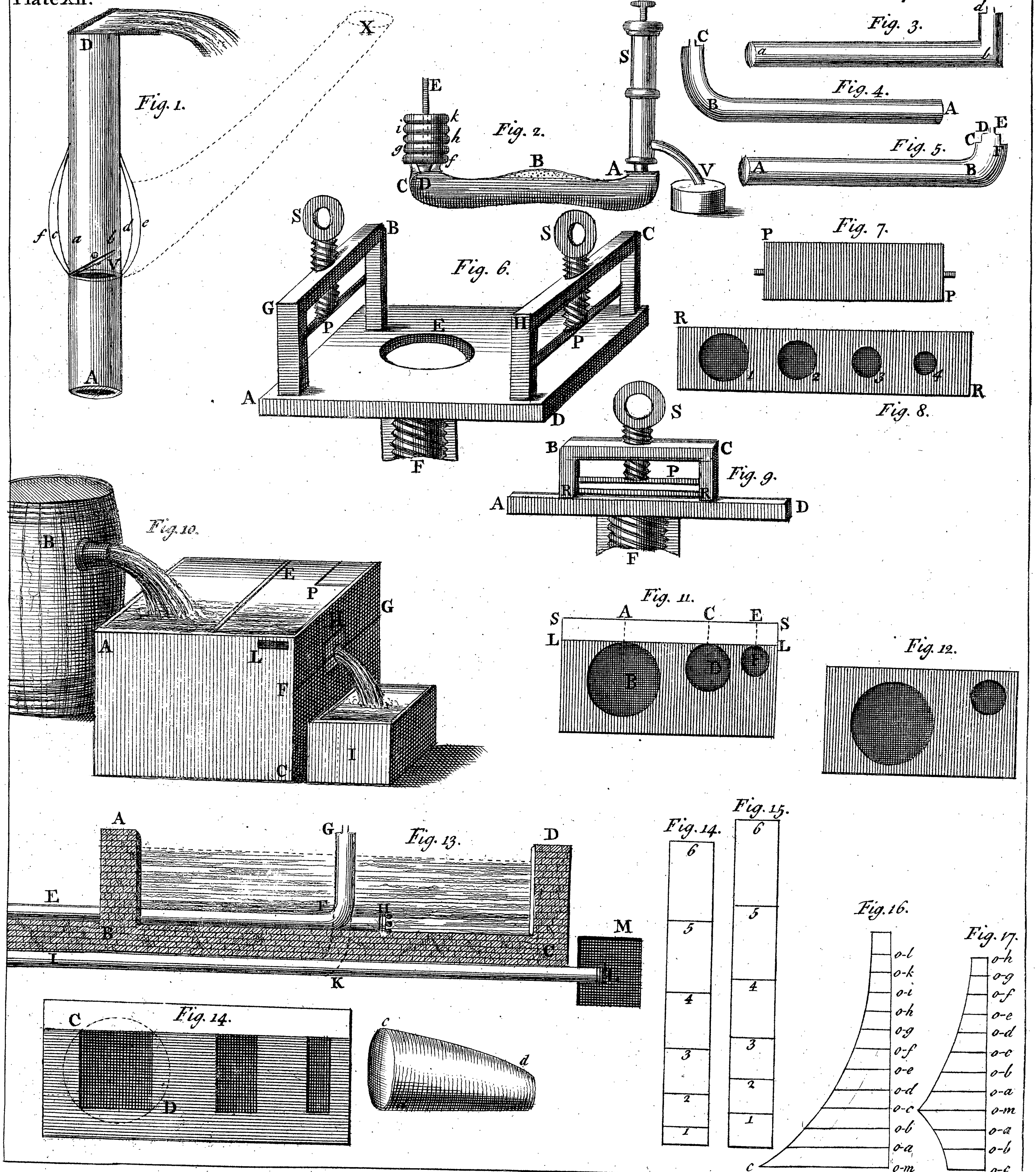
If there be a Curve and Asymptote, *Fig.* 16. *c o m l o*, whose Ordinates *o m*, *o—a*, *o—b*, *o—c*, *o—d*, *&c.* represent the Density of the Air in Winter, reckoning from the Ground upwards; the Curve must turn again towards the Asymptote coming down to the Earth, that the Ordinates may represent the Density of the Air in Summer: that is, if *o m*, *Fig.* 17. represents the Density of the Air at the coldest Region (suppose at top of a Mountain) *o—a* will represent it lower, *o—b* still lower, and *o—c* at the Bottom, or in the Valley.

Plate 12. Fig. 16, 17.

10. [23.——*Air whose Elasticity is perfect when it is pure Air, &c.*] I call that Air pure, which after it has been rarefied by Heat, or condensed by Cold; (rarefied by the removal of the ambient, or of the superiour Air, or condensed by Pressure from the Accumulation of the superiour Air, or any other way) upon the Removal of those accidental Circumstances, returns to its former Tenor or Density. Thus Air, that has been condensed in a Wind-Gun, will keep all its Force, tho' it be shut up for Years. It has been found

Plate XII.

pa. 142.



J. Mynde sc.

found at 7 Years end, nay after 16 Years, to have all the Force it had the first Day it was condens'd, and to be capable of dilating it self to the same Dimensions that it had before it was driven into the Gun. But if we consider things strictly, there is no Air wholly unchangeable; because acid and sulphureous Vapours will (as it were) absorb it, and change it from an elastick into a fix'd State, as we shall shew when we come to treat fully of the Nature of the Air; what we have now said being sufficient for our present Purpose. Annotat. Lect. VII

11. [24.——*The Air is of the same Density at the same Level, unless where it is accidentally heated or cool'd.*] Upon chalky and sandy Shores, the Soil being heated, rarefies the Air by its warm Reflection in such manner, that it is thinner than the neighbouring Air over the Sea; but by help of its Heat it has Force enough to keep the colder Air *in æquilibrio*, nay and sometimes to drive it away, so as to make a Wind towards the Sea call'd a Land-Breeze in the Day-time: but at Night, when the Shore being no longer heated by the Sun, the Air over it, ceasing to be dilated, returns to its former Density, whilst the Air from the Sea rushing in, makes the Sea-breeze.

12. [25.——*This will succeed whether the Cock be open or shut.*] Because when the Cock is shut, the Air included in the Receiver, as it is of the same strength as the outward Air, pushes the Bladder as strongly into the Cupping-Glass, whose Air is now much thinner, as the outward passing thro' the Cock wou'd have done. There is only a very small Difference owing to this, *viz.* that the Air in the Receiver when the Cock is shut, cannot push the Bladder towards the Cupping-Glass without expanding it self a little, whereby it becomes a little weaker than if the Cock was open; but as the Encrease of Space of the Air of the Receiver is but very small in Proportion to its whole Contents, the Decrease of its Spring to weaken it, is almost insensible.

LECTURE

LECTURE VIII.

HYDROSTATICKS.

Lect. VIII. 1. A Syphon is a bended Pipe, one end of which being put into a Veſſel of Liquor, and the other hanging out of the ſaid Veſſel over another Veſſel, the Liquor will run from the firſt into the laſt after the Air has been ſuck'd out of the external, which is the lower End of the Syphon, and that as long as the Liquor in the upper Veſſel is above the upper Orifice of the Syphon.

Experiment 1. *Plate* 13. *Fig.* 1.

Plate 13. Fig. 1. HDS is a Syphon, whoſe two Parts HD, DS are call'd its Legs; and by its Operation the Water is drawn out of the upper Veſſel ABCD into the lower *ab*. When you have ſuck'd out the Air at S, the Water follows coming in at H, going in the Direction HGDS, and out at S, as long as the Surface EF is above IH, the Level of the Mouth of the *driving* Leg of the Syphon. NB. *We call* driving Leg, *that in which the Water goes up*; *and* iſſuing Leg, *that thro' which it goes down, and ſo out. But we can properly call* ſhort Leg *of the Syphon, only that Part of the* driving Leg, *which is above the Water in the upper Veſſel, from which the Water is drawn, as the Part* DG; *becauſe tho' the Orifice or Mouth of the Syphon is at* H *much lower than* I, *yet the Columns of Water contain'd between the Surface* EF, *and the imaginary Surface* IH *at the Level of* H, *do keep in æquilibrio the Column of Water* GH *in the lower part of the* driving Leg DH, *for which Reaſon it operates only as if the Orifice was at* G. *

* Ann. 1.

2. Now the Cauſe of the Syphon's running is this. The Air which preſſes into the Veſſel ABCD, repreſented by the Column KL, ſuſtains the Column of Water LD in the ſhort Leg of the Syphon, preſſing againſt that Air with its perpendicular Height DF, whilſt the Column of Air MS preſſing upwards againſt the Hole of the *long* or *iſſuing* Leg D (which acts according to the Height DC) muſt yield and ſuffer the Water to run out as long as the Leg DS is longer (or rather higher in Perpendicular) than DG.

D G. For since K and M are suppos'd at top of the Atmosphere, the Columns K L and M S are equal in Height and Pressure, (for the Height of L above S is of no account in an Height of about 60 Miles) as long as M S is acted upon by the descending Water D S, whose Height is from D to S, (suppose of 15 Inches) an Height superior to that of the Column D G, (suppose of seven Inches) supported by the Column of Air K L, the Column M S must yield to the Water issuing out at S: and however the Surface of the Water E F descends, the Column K L, by its Pressure, will always overcome the Resistance of the Column M S, because it has a less Height of Water to sustain than M S has. If the Mouth of the issuing Leg had been at T, the Water would hang *in Æquilibrio*, filling both Legs of the Syphon, when the Water is come down in the upper Vessel to I H T, because then the two Columns of Air K L and M S will be acted against by an equal Height of Water in the Legs of the Syphon; but if then you raise the issuing End of the Syphon, (now suppos'd at T) up to the Level of *u* V above I H, the Water will run back up from V to D, and so out at H in the upper Vessel; because then the Column M S, having only the Height V D to sustain, will be acted against with less Force than the Column K L, which is press'd against by the whole Height D H superior to V D.

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Plate 13. Fig. 1.

3. Since the Pressure of the Air * is the Cause of the Water being push'd up into the Syphon, and the Difference of its Pressure (as one Column is acted against by the Water in the short Leg more weakly than another Column of Air is acted upon by the Water in the long Leg) is the Cause of its running continually from one Vessel into another, when once set a going; it follows, that the Bend D of the upper Part of the Syphon must not be above 32 Feet higher than the Water in the upper Vessel, because the Air cannot sustain a Column of Water, whose Height exceeds 32 Feet. If therefore there was a Crane or Syphon A C E D B, *Fig.* 2. of about 40 Feet high, reckoning from A to E, with Cocks A and B at its lower Ends, and an Hole at top E, to be stopp'd with a Cork upon occasion, there might be made the following

* Ann. 2.

Experiment 2. *Plate* 13. *Fig.* 2.

Water being pour'd into the Vessels A and B, let the Cocks A and B be shut: then with a Funnel pouring in Water at E, till both Legs of the Syphon are full, stop up the Hole E; and open the two Cocks at once. The Water, instead of running from the Vessel A into the Vessel B, which it would do if the Height C A was much under 32 Feet, will in the two Legs fall back to C and D 32 Feet above A and B, where it will

Plate 13. Fig. 2.

 hang,

Lect. VIII. hang, the Air not being able to sustain the Water above those Heights, and consequently to drive it up over the Bend E. Nay, unless the Water be purg'd of Air before the Experiment, the Top of the Water at C and D will not be quite 30 Feet above the Water in the Vessels A and B, because Air will extricate itself out of the Water, and getting into the Cavity C E D, press a little on the Top of the Water at C and D, so that its Height will be less to balance the Pressure of the Atmosphere.

Plate 13. Fig. 2.

* Ann. 2.

4. MERCURY will run in a Syphon in the same manner as Water; but only the Bend of the Syphon must not be more than 30 Inches and $\frac{8}{10}$ above the stagnant Mercury in the upper Vessel *; because as it is near 14 times specifically heavier than Water, it will be lifted up by the Pressure of the Air but the 14th Part of the Height that Water is lifted.

5. To prove further, that a different Pressure against the Orifices of the unequal Legs of a Syphon is the Cause of a Liquor running thro' that Instrument from an higher into a lower Vessel, we may make use of any other Fluid, (lighter than the Fluid to be brought over) instead of Air, and leave the Bend of the Syphon open to the Air, as in the following

EXPERIMENT 3. *Plate* 13. *Fig.* 3.

Plate 13. Fig. 3.

A B C D is a pretty large Glass Jar, with a little Water (ting'd red to make the Experiment conspicuous) in its Bottom to the Height of an Inch, as at E F. On a Stand between F and G in the great Jar, there is placed a little Jar G H K I, almost full of the said red Water. Let down the Syphon S L M G (open at S, M, and G) into the Vessel, so that the End S of the long Leg stands in the Water at Bottom of the great Jar; and G, the End of the short Leg, in the little Jar at the Bottom of its Water. Pour in Oil of Turpentine into the great Jar up to L, so that the Water in the little Jar may also be cover'd with it, and the Water will first rise up in both Legs of the Syphon, so as to meet at the Bend at L; then it will run out of the little Jar into the great one, thro' the Syphon in the Direction G H L S, as long as there is any Water in the little Jar above G.——*Which proves what we have asserted.*

6. WHEN a Syphon is inverted, as A C D E, (*Fig.* 4.) the long Leg A C becomes the driving Leg, and the short Leg D E becomes the issuing Leg; then if a Vessel, as V W, keeps the Syphon supplied with Water at its upper End A, the Water will spout out at the lower End E,

and

and riſe up to G, (an Height proportional to the Height of A above E) provided the Hole at E be contracted ſo much, that the Syphon may ſupply it fully, becoming a proper Ajutage for the Conduct A C D E, according to the Rules for Jets given in our laſt Lecture *. The Velocity of the Water ſpouting out at E will be proportionable to the ſquare Root of A B, the Height of the Surface of the Water at L L above *l l*, the Level of the Ajutage. But tho' this be true, when the Water has ſpouted ſome time; yet at firſt the Water begins to ſpout with a much leſs Velocity; as, for example, riſing only to F, then by degrees encreaſing its Velocity, till at laſt it comes up to G, to which Height it continues to riſe, as long as the Syphon is ſupplied. This is owing to the Depth of the Body of Water in the driving Leg, and the iſſuing Leg below the Line *l l*, level of E, which muſt be put into an uniform Motion, before the Jet has acquir'd its full Velocity: ſo that if the Part of the Syphon below *l l* goes down to a great Depth, the Velocity of the riſing Water will be the leſs at firſt, till E D has receiv'd its proper Motion. So that if there be ſeveral ſuch Syphons as we have deſcrib'd, with their upper Orifices at L L, level of A, and their lower Orifices at *l l*, level of E, but with their bended Parts B C D E going down to different Depths below E, the Water at its firſt ſpouting will riſe higher from that which has E D, the ſhorteſt, going to the leaſt Depth below *l l*: See *Figure* 5. where E F goes higher than E F in *Fig.* 4. and *Fig.* 6. where E D being of no Height, E F, the Jet, goes to the full Height at firſt. *Monſ. Belidor*, in his *Architecture Hydraulique*, was the firſt who took notice of this, other Hydraulic Writers having only conſider'd the utmoſt Height of a Jet, which is according to the ſquare Roots of the Height of A above E, (for this Syphon and Veſſel is the ſame as a Reſervoir and its Conduct-Pipe) and took no notice of the Reaſon why Jets do not riſe to their utmoſt Height, for ſome time after a Cock is open'd to play them.

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* L. 7. Ann. 5. Page 130, and 131.

Plate 13. Fig. 4, 5, and 6.

MONS. *Belidor*'s Rule to find out the Velocity of E F, the Water firſt ſpouting, is this, *viz.* E F is as the Root of the driving Leg A C, *minus* the Root of the iſſuing Leg D E, or $\sqrt{AC} - \sqrt{ED}$. Whereas the Velocity of E G, only conſider'd hitherto, is as the Root of the driving and iſſuing Leg, or as $\sqrt{AC - DE}$. This may not only be found by Calculation, but prov'd by Experiment.

EXPERIMENT 4. *Plate* 13. *Fig.* 4, 5, and 6.

LET V W (*Fig.* 4.) be a Reſervoir, from which the Pipe of Conduct A B deſcends to a Depth of 25 Feet, and riſes again at D E to an Height of nine Feet: if the Finger, or any other Stop (after the Cock, not re-

Lect. VIII. presented here, is open) be held at E, and then suddenly taken off, the Water will spout at first but to F, 7,6 Feet high, and rise by degrees, till it comes at last to G = 15,2 Feet. In *Fig.* 5, let A C be 20 Feet high, and D E, 4: the Water E F will rise at first 9,4 Feet, and at last E G 15,2 Feet, as before. But in *Fig.* 6. the descending Pipe be but 16 Feet deep, B C and D E being then of no Height, (the Ajutage E being always understood to be at the same Level) the Water E F at its first spouting will rise to its utmost Height, *viz.* 15,2 Feet. The Calculation for *Fig.* 4. is this, $\sqrt{AC - DE} : \sqrt{AC} - \sqrt{DE} :: EG : EF$; that is, $\sqrt{25 - 9} = \sqrt{16} = 4 : \sqrt{25} - \sqrt{9} = 5 - 3 = 2 :: 15{,}2 : 7{,}6$. The Calculation for *Fig.* 5. where $BC = DE = 4$, is as follows,

Plate 13. Fig. 5, 6.

$$\sqrt{AC - DE} : \sqrt{AC} - \sqrt{DE} :: EG : EF; \text{ that is,}$$
$$\sqrt{20 - 4} = \sqrt{16} = 4 : \sqrt{20} - \sqrt{4}\ (= 4{,}47 - 2) :: 15{,}2 : 9{,}4.$$

As for *Fig.* 6. both Expressions give the same 15,2, because B D or C D are equal to nothing.

N. B. This Experiment cannot be try'd in Models of an Inch to a Foot, because unless the Ajutage be nearly of a quarter of an Inch Diameter, the Jets will not rise proportionably, by reason of the Attraction of Cohesion on the Circumference of the Hole, as we have shewn in *Lecture* 7. *Note* 7. *Page* 138.

This Consideration of Monf. *Belidor*'s is of great use in making of Pumps, but we shall not speak of the Application of it, till the Nature of Pumps has been explain'd; therefore we must refer the Reader to the Notes upon that Subject *; and return to a further Examination of Syphons.

* Ann. 3.

7. Instead of hanging a Syphon over the Side of a Vessel, it may be adapted to a Cup, so that the short Leg being in the Cup, the long Leg may go down thro' the Bottom of the Cup; see *Fig.* 7. on which may be made the following

Experiment 5. *Plate* 13. *Fig.* 7.

Plate 13. Fig. 7.

The Syphon D S being fix'd to the Cup E F, pour Water into it as high as E F, and the Cup will hold Water; but if you pour Water up to G H, above the Bend of the Syphon D, the Water will begin to run out thro' the *issuing Leg* at S, going up the *driving Leg* at A, till the whole Water is run out of the Cup. Where you are to observe, that whilst the Water is above D, the bent Pipe is not a *Syphon*, but a *waste Pipe*, of the same Use as if it had only an Hole at D, thro' which the Water came down; because the *driving Pipe* A D being fill'd only by the

the Pressure of the Columns of Water between G H, and the Level of A, can only be call'd the *short Leg* of the Syphon, when the Water being fallen below D, the Air begins to press, and raise up the Water into A D. If a double Pipe, as P, open at Bottom, and close at Top, whose inner Pipe is open at both Ends, be fix'd to a Cup, instead of the Syphon A D S, it will perform the same Office as the Syphon; for upon filling the Cup, the Water will be push'd into the great Pipe between the two Pipes at *o o*, till, when it comes to the Top, it runs down the small or inner Pipe, first as a *waste Pipe*, then as a Syphon. The eighth Figure shews such a Pipe fix'd in a Cup, as A B, where the Water's Surface being at S S, the Water at Bottom runs up into the double Pipe at *o o* up to P *p*, then down the little Pipe at Q, and out at R, under the Foot of the Cup; the Interstice of the Pipes being instead of the driving Leg of the Syphon. Lect. VIII. Plate 13. Fig. 7, 8.

A Cup of this sort is commonly call'd a *Tantalus Cup*, because an Image, representing *Tantalus* in the Fable, is fix'd up in the middle of the Cup, to hide the double Pipe; and then when the Water is fill'd up to the Breast of the Figure, the Cup will hold without spilling; but as soon as it is fill'd up to the Chin of *Tantalus*, (which is above P *p* in *Fig.* 9.) the Water will begin to run thro' the Syphon, conceal'd by the Figure, till the Cup is quite emptied, in the manner explain'd before. See *Fig.* 8. Plate 13. Fig. 9, 8, 11, 10.

Sometimes the *Tantalus* Cup is made without a Figure fix'd in it, as in *Fig.* 11. where the Water being up at S S, the Cup does not run; but as soon as the Figure, or an Apple, or Orange, *&c.* is thrown in, the Water begins to run out at the Foot of the Cup, and does not cease till the whole Cup is empty. This happens, because the Bulk of the Body thrown into the Cup raises the Water's Surface from S S to B C, where being above the upper End S of the Pipe S P, conceal'd in the Handle, (which thereby is made a Syphon) the Water which is come into the Handle at O runs into the middle Pipe at S, and so out at P, under the Foot, as long as there is any Water above O.

There are some Syphons, thro' which the Water will run out of a Vessel, without sucking the Air out of them, or making them in the manner of a waste Pipe, as we have just describ'd. But those must be made of capillary Tubes, whose Bore must not be bigger than $\frac{1}{10}$ of an Inch, and as soon as they are put into a Vessel of Water, (as T *s* S, *Fig.* 10.) they will begin to run, and so continue as long as there is any Water above the *driving Leg*. This happens because the Attraction of Cohesion, which makes Water rise up in small Tubes, draws the Water from the Surface V to W in the Syphon; where being lower than the Surface of the Water in the Vessel, it must run down, because the Column of

Water

Lect. VIII. Water W *S* is longer or higher than the Column *S* V, and the Air pushing down at V must overcome the Resistance of the Air pushing upwards at S. For the same reason a piece of List of Cloath A D will make the Water come out of the Vessel, and fall down in Drops at E, as this piece of Cloath is in effect a Bundle of capillary Syphons made by its Interstices. But if the Surface of the Water in the Vessel was at *g h*, the Syphon being put in would not run out, but only rise in the Syphon up to *e f*, the Height to which a Tube of that Bore would raise the Water by the Attraction of Cohesion. When the Vessel is full, this Experiment will succeed *in vacuo* *.

Plate 13. Fig. 10.

* Ann. 2.

8. In the Year 1724, I attempted to account for the rising and falling of the Water of some Ponds near the Sea, or ebbing and flowing Rivers; where the Water is lowest in the Pond, at the time of high Water in the Sea or River; and the Water is highest in the Pond, at the time of low Water in the Sea or River: As also for the increasing or decreasing of the Water of such Pools and Brooks as are highest in the dry Seasons, and lowest in the rainy Seasons. And this I did by supposing some Ponds to have an Issue at Bottom into the Earth, which rising again under Ground up almost to the Level of the Top of the Pond, should descend below the Bottom of the Pond; because such Cavities, however irregular, if tight, would do the Office of a Syphon. For this reason I call'd such a Pond a *Tantalus*, and an *hidden Tantalus* a subterraneous Cavity, holding Water, and having such an Exit, which is as likely as an horizontal Passage. To illustrate this, I made some Experiments.

Experiment 6. *Plate* 13. *Fig.* 13.

Plate 13. Fig. 13.

In the Vessel *a b c d* is placed an open wooden Box A B C D fill'd with Water as high as the Line L M. Another Box or Plug E F G H made tight, and containing Weights to sink it, is made to let down into the Water between the Partition I K, and the End A B of the Box abovemention'd; but when it is not to press the Water up to I O, (as it does when let down) it is drawn out of the Water by the Weight *m*, which pulls it up by the Bar *i k* fasten'd to a Lever moving round the Center *l*.

When by means of the Plug, the Water in the Space A B K I is push'd up to I O, by passing under K; it runs out thro' the Spout P Q, (whose Passage is gaged by a little Sluice P *p*) and falls into the Vessel R S made of an oblong Figure like a Fish-Pond, and having a Syphon at S, so as to make it a *Tantalus*, or in the Nature of the Cups abovemention'd. Let the Weight *m* pull up the Plug E F G H, and the Water, having fill'd R S, will run down below the Orifice P to M.

The

The *Tantalus* R S, beginning to run out as soon as full, will, for the Reasons above given, continue to run till it is all emptied: and as it discharges itself into another *Tantalus* T V, (whose Syphon is at V) this last *Tantalus* will also, when full, begin to run out, and its Water go down to *x* Y *o*. Plate 13. Fig. 12.

If the Plug be let down gradually, as soon as the Water begins to run out of the last *Tantalus* T V, (and the first *Tantalus* R S be cover'd so as to be conceal'd from Sight) it will appear to the Lookers on, that the Cavity T V, representing a Pond near an ebbing and flowing River, (as I am credibly inform'd there is such an one at *Greenhive* in *Kent*, between *London* and *Gravesend*) always rises, whilst the Water at N O (or the Tide) falls to L M; and always sinks whilst the Water at L M (or the Tide) rises to O L.

Experiment 7. *Plate* 13. *Fig.* 12.

9. Let the Water in the Box A B C D not be made use of; only the Vessel Z be fill'd every half Hour: it will empty itself in the space of a quarter of an Hour, falling like Rain, and dropping also thro' the leaden Platform *e f* into the hidden *Tantalus* R S, which will not begin to run till this artificial Rain is over: then in a quarter of an Hour more, the *Tantalus* R S will have emptied itself into the visible *Tantalus* T V, which will be filling all the time after Z has done running, (or in the dry Season;) and as soon as T V is full, it will begin to run out thro' its Syphon V, at the end of the half Hour, when the Vessel Z, or Sieve, runs again; that is, at the return of the rainy Season. Plate 13. Fig. 12.

This last Experiment may be easily applied to those Ponds, or those Brooks, that are high in dry Weather, and low in wet Weather; of which kind, I am told, there is a Brook at *Lambourn* in *Berkshire*.

10. If it be objected, that such Ponds are full for some time, which a *Tantalus* cannot be, because it begins to run as soon as full; that may be easily solv'd, by supposing the hidden *Tantalus* (or intermediate Cavity between the River and Pond) to contain more Water than the visible one, provided it does not contain so much as not to be emptied before the Return of the Tide.

The same Solution will serve for wet and dry Seasons, only supposing the Cavities larger.

If it be asked, where the Water of the visible *Tantalus*, near a River, can run; it may be answer'd, that all this may happen, if the second, or lowest *Tantalus*, has its Bottom higher than Low-Water Mark in the River. And for the Syphons which are of a particular Make in the Cup;

tho'

Lect. VIII. tho' ſuch be not ſuppos'd in the Earth, yet any long Paſſage riſing in the Middle will anſwer the End. See *Fig.* 13. where A B C D repreſents the Channel of a River, A D High-Water Mark, and G H Low-Water Mark; Z I a Paſſage from the River to the Cavity I K L M N, or firſt, or hidden *Tantalus*; L M Q the Syphon of the firſt *Tantalus*, running into the ſecond *Tantalus*, or viſible Pond O Q R P, which by its Syphon R S V runs out into low Grounds, that may be above the Low-Water Mark G H; and the Bottom K L of the firſt *Tantalus* may be above the Top of the laſt, whoſe Level is the Line W W.

Plate 13. Fig. 13.

A B C D Y O Q R P V H is the Section of the Surface of the Earth.

Dr. *Atwell* Rector of *Exeter-College* in *Oxford*, has in the Phil. Tranſactions, Numb. 424. very ingeniouſly explain'd ſeveral Phænomena of reciprocating Springs by Syphons *.

* Ann. 4, 6.

Of PUMPS.

11. The common Pumps conſiſt of a Pipe open at both Ends, in which there is a ſliding Piſton, of the ſame Bigneſs as the Bore of the Pipe, which by means of the Hand, or any other Contrivance, can be mov'd up and down, without letting any Air get between its Sides and the Pipe.

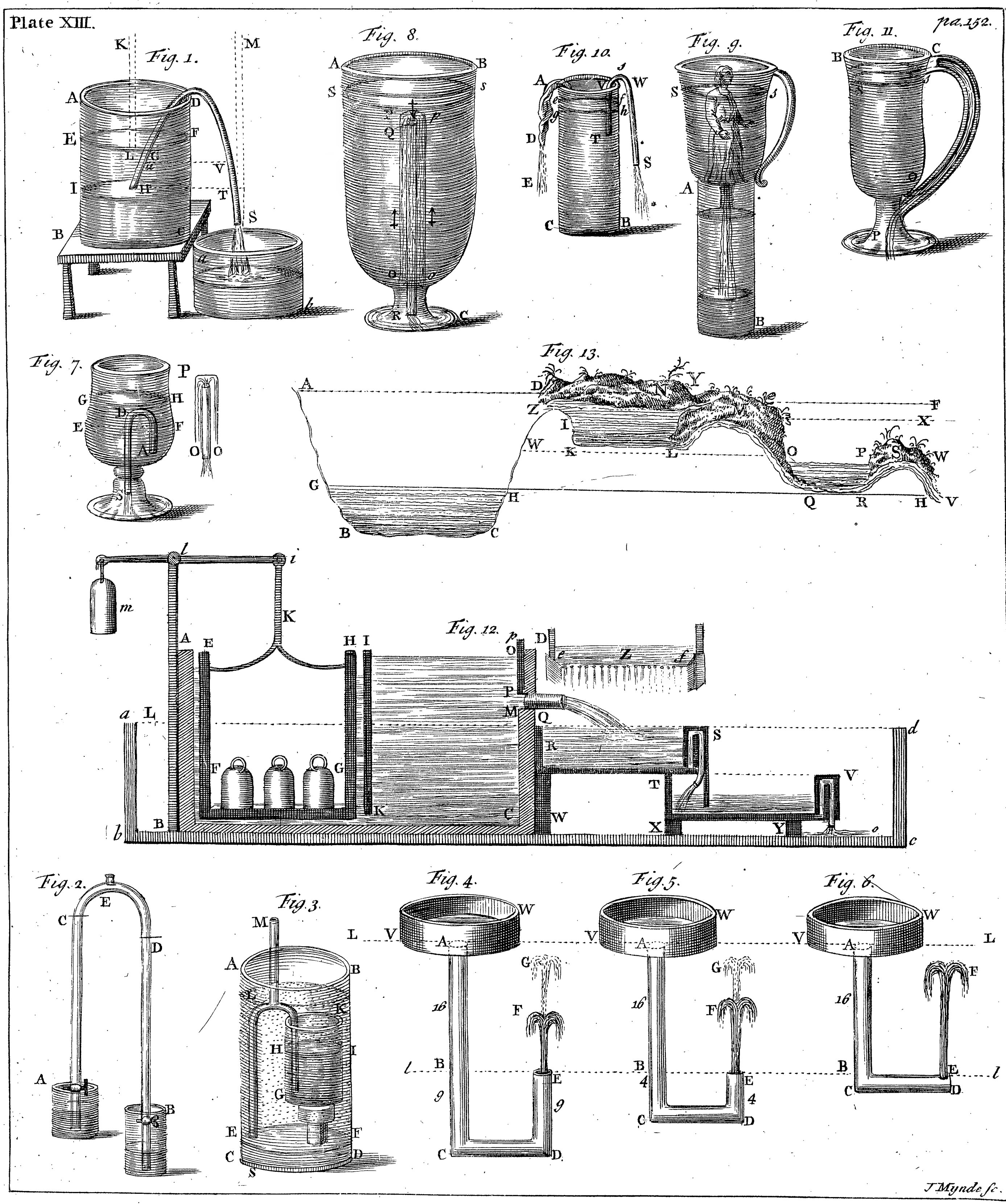
If the lower End of the Pipe be put into Water, and the Piſton, after having been at the Bottom, be moved upwards, it makes a Vacuum in the Pipe, and conſequently the Atmoſphere preſſing upon the outward Water, will make it riſe in the Pipe to about 32 Feet, and ſometimes a little higher *; becauſe a Pillar of Water of ſuch an Height being equal to the Weight of a Column of Air of the ſame Bigneſs, but reaching in Height to the upper Surface of the Air, will hold it *in Æquilibrio.*

There are two ſorts of Piſtons, the one with a Valve, which is call'd a Bucket; and the other without a Valve, which is call'd a Forcer: The particular Conſtruction of them I ſhall afterwards explain.

That

* *N. B.* The Air being ſometimes heavier, and ſometimes lighter, the Water will riſe to different Heights, according to the Weight of the Air at the time that the Pump works; and therefore the Water may riſe up to 35 Feet and an half, (as it does when the Mercury in the Barometer is 31 Inches high) but that Nicety not being neceſſary here, we have taken 32 Feet for our Standard Height, it being the leaſt Height, or that to which the Water can riſe when the Mercury in the Barometer ſtands at 28 Inches. It is alſo to be obſerv'd, that the Air in the Pipe under the Piſton, whilſt it is of the ſame Denſity as the external Air, preſſes as much on the Water in the Bottom of the Pipe, by its Spring, as the Atmoſphere, or external Air preſſes upon the Water in the Well; but preſſes leſs and leſs, in proportion as it is rarefy'd by the working of the Piſton. As, for example, if it be dilated or rarefy'd one half, it preſſes but with half its Force, and the Water will riſe 16 Feet under the Preſſure of ſuch Air; 16 Feet in Height of Water, together with the Preſſure of that Air, being juſt a Balance for the Atmoſphere, which puſhes up the Water 32 Feet high, only when the whole Air is quite out of the Pipe.

Plate XIII. pa. 152.



J Mynde sc.

That Part of the Pipe where the Piston moves is call'd a Barrel.

12. There are three sorts of Pumps, the sucking, the lifting, and the forcing Pump.

The sucking Pump consists of a Pipe A B, *Plate* 14. *Fig.* 1. open'd at both Ends, in which there is a sliding Bucket, made in such a manner as to let no Air get between its Sides and the Barrel, when it moves up and down. This Bucket has a Valve (n) which opens, *when it is push'd upwards, by the descending of the Bucket*, and shuts again, *when it is push'd downwards, by the rising of the Bucket.* Plate 14. Fig. 1.

There ought to be another Valve (v) in any place of the Barrel, not above 32 Feet from the Surface of the Water, which opens when it is push'd upwards, and shuts when it is push'd the opposite way.

Then if the lower End (B) be in the Water, and the Bucket, which before was at (M), be rais'd to E; as it lets no outward Water get through its Sides, nor through the Valve, (which then is shut by the Weight of the outward Air) it makes a Vacuum in the Pipe, or at least very much dilates the Air in it; then the Atmosphere pressing more strongly upon the outward Pipe, than the dilated Air does in the Pipe, makes the Water rise in the Pipe, 'till it comes to such an Height, that, together with the Air (still a little rarefy'd in the Pipe,) it may have a Weight equal to the outward Air. Then if the Bucket be mov'd downwards again, its Valve opens, and lets the Air come up, and go freely out; at the same time, the Valve (v) being push'd downwards by the descending of the Bucket, shuts, and hinders the Water, which was got up in the Pipe, from going down: if then the Bucket be mov'd upwards again, the same will happen, as before, and the Water will always rise in the Pipe, 'till it comes to the Bucket, provided it be not above 32 Feet from the Surface of the outward Water; and then the Bucket, when it goes down, lets the Water thro' its Valve, which being shut again as it goes upwards, never lets it go down, and consequently Water may thus be rais'd to any Height desir'd, provided the Power be sufficient to raise its Weight, and the Pipes strong enough to bear the lateral Pressure. For the Weight of the Water is always as the Section of the Bucket, multiplied into the Height of the Water, and the Pressure against any Part of the Pipes is as the Height of the Water above the said Part, multiplied into the Surface of that Part.

13. The lower the Bucket goes in the Pipe, the better will the Effect be. In order to prove it, I'll endeavour to shew several Inconveniencies which are to be met with when the Bucket is at a great distance from the

Lect. VIII. the outward Water. Let us suppose the Bucket to be at 17 Feet from the Water, when it is at the lowest; and 18, when at the highest. When first the Bucket moves upwards from 17 to 18, then the Air in the Pipe, (which before the rising of the Bucket was contain'd in a Length of 17 Feet, and now is contain'd in 18) being rarefy'd by $\frac{1}{18}$, presses upon the Surface of the Water but with $\frac{17}{18}$ Parts of the Force it acted with before; and therefore the Pressure of the outward Air causes the Water to rise in the Pipe, 'till, together with the Air still a little rarefy'd in the Barrel, it has a Pressure equal to that of the whole Atmosphere. For the same reason the Water will rise at the second Stroke, and so on. But if you suppose Water pour'd into the Pump, 'till it comes to 16 Feet above the Water in the Well, it is evident that the Air contain'd between the 16th and 17th Feet is made twice rarer when the Bucket goes up to 18; and therefore, that its Pressure is diminish'd by $\frac{1}{2}$, which $\frac{1}{2}$, together with the 16 Feet of Water, (equal to half the Force of the Atmosphere) is equal to the whole Weight of the outward Air, which therefore is not able to make the Water rise any higher in the Pipe. But if the Play, or Stroke of the Bucket, were more than one Foot; as, for example, two, (the Water being suppos'd to be up to 16,) the Bucket would by its going up from 17 to 19 diminish by $\frac{2}{3}$ the Pressure of the Air in the Pipe, so that the Water to supply those $\frac{2}{3}$ would rise high enough to go thro' and above the Valve of the Bucket at its Descent to 17.

14. Hence it is evident, that the greater is the Distance of the Bucket from the Surface of the Water in the Well, the greater ought its Play, or Length of Stroke, to be. So that if the Bucket was 30 Feet from the Water, its Length of Stroke should at least be 480 Feet, to make the Water at the first Stroke rise as high as its Valve, which Length of Stroke would be very troublesome to give, if not impossible.

15. There is another Inconvenience which can easily happen, if the Bucket be distant from the Well; namely, that if the least Hole should happen to be in the Pipe lower than the Bucket, the outward Air getting thro' it would hinder the Rarefaction of the Air in the Pipe, and consequently the Pump would have no Effect.

Both these Inconveniencies will be avoided, if the Valve of the Pipe be at the Bottom of it, in the Water, and the Bucket goes quite down to it; then how short soever the Stroke be, it will bring the Water up; and if any Hole happen to be in the Pump, it will cause but some loss of Water, and not hinder the Effect of the Pump. And then the Valves being

being continually in Water, their Leathers will be kept wet, and therefore perform their Office better than if they were dry. Lect. VIII.

Besides, it will not be requir'd to have a greater Power to give Motion to the Bucket, if it works at the Bottom of the Pipe, than if it was to work at 32 Feet above the Surface of the Water; for as in this last case a Vacuum must be made under the Piston before the Water can rise 32 Feet high, it is evident that then the Piston supports (or is press'd down by) the whole Weight of the Atmosphere, which is equal to the Weight of a Pillar of Water 32 Feet high, and of the same Bigness as the Piston: but when the Piston, working in Water, lifts 32 Feet of Water above it, that Water is all that it lifts, because then the Air pressing on the Piston, is balanc'd by the Air pressing on the Surface of the Water, just as if the Air had not been concern'd in the Operation.

If the Piston works at any Distance above the Surface of the Water to be drawn up, under 32 Feet; then, besides the Water which is above it, it sustains some Part of the Weight of the Air: for when the Atmosphere pressing the Water in the Well raises it up to the Piston, some of its Force is spent to drive up that Water in proportion to its Height, and consequently it can only balance so much of the Air pressing above the Piston, as it has Force left. For example, if the Piston works at eight Feet above the Surface of the Water, the Pressure of Air on the Piston is equal to $\frac{1}{4}$ of the Weight of the Atmosphere, the Remainder of the Pressure being balanc'd by the remaining Force of the Air in the Well. Now as the Air pressing in the Well is able to support 32 Feet of Water, when it supports but eight, or $\frac{1}{4}$ of it, its remaining Force must balance, or take off the Pressure of $\frac{3}{4}$ of the Force of the Air on the Piston.

Hence the Water under the Piston, from the Piston to the Surface of the Water in the Well, may be consider'd as a Weight hanging under the Piston, because it is equal to the Pressure of the Air above it; and without taking any notice of the Air, we may always say that the Piston is loaded with all the Water under, as well as above it; and to raise it there must always be applied a Power greater than the Weight of a Pillar of Water of the Bigness of the Piston, whose Height is equal to the Height to which the Water is rais'd above the Water in the Well.

16. There are some Cases, where the Pump is not perpendicularly over the Well; as, for example, if one would raise Water out of a Well at A, *Fig.* 2. by means of a Pump at B; then the best way will be to make the Barrel go as low, or a little lower than the Well, as far as C, and to make the Bottom C of the Barrel communicate with the Well by means of a Pipe A C, which has a Valve in any Part of it; then if the Plate 14. Fig. 2.

Lect. VIII. Bucket plays at the Bottom C of the Barrel, it will have the ſame Effect as if the Well were perpendicularly under the Pump, becauſe the Water runs by its own Weight down the Pipe A C.

But ſometimes it happens, that by ſome Impediment the Barrel cannot be made to go as low as the Well, and then the Pipe under the Barrel being very long, would conſequently require a long Stroke of the Bucket: This Inconveniency may be avoided by making the Pipe of a ſmaller Bore than the Barrel; for then the Bucket will by a leſs Stroke rarefy the Air enough in it to make the Water riſe to the Valve. See the *Figure* 3 at *z*.

Plate 14. Fig. 3.

The ſame can otherwiſe be made by pouring Water in the Pipe to a greater Height than where the Bucket plays; for then, as there is no more occaſion for rarefying the Air, the Pump will perform its Effect, as long as every thing is in a good Condition.

This way has this Advantage above the firſt, that the Water has not ſo great Velocity in the Pipes, as when they are made of a leſs Bore than the Barrel.

17. There are ſeveral kinds of Buckets; the moſt ſimple of all, which is commonly uſed for ordinary Pumps, conſiſts of a cylindrick piece of Wood C C, *Fig*. 4. having in its middle a Hole E quite thro' it. This cylindrick Wood ought to be a little leſs in Diameter than the Bore of the Barrel, that it may move freely up and down in it; there is at its Top an Iron Piece A A, faſten'd to another Piece F, being a Rod of Iron or Wood, which goes quite to the Top of the Pump, and by means of which the Motion is given to the Bucket.

Plate 14. Fig. 4.

Near the Top of the cylindrick Wood C C, there is a leathern Ring B B, *Fig*. 5. faſten'd round it, which goes a little higher than its Top; the Hole E is ſtopp'd by a Valve, made of a round Leather (*e e*) faſten'd to the cylindrick Piece of Wood in any Place (*c*) of it, by means of ſome Nails. There is upon it an Iron Plate (*d d*) a little larger than the Bore of the Hole E, and another Iron Plate under it (*g g*,) a little leſs than the Bore of the ſame Hole E, thoſe two Plates and the Leather are faſten'd together by means of a Rivet or Screw (*n*) in the middle of them.

Plate 14. Fig. 5.

Then it is evident, that if the Bucket be put in the Barrel, the Leather B B B, *Fig*. 6. being wet, will apply itſelf to the Sides of the Barrel, when the Bucket is mov'd up and down, in ſuch a manner as to hinder any Air from getting between them. Moreover, when the Bucket goes down, the Air in the Pipe, (provided it be of the ſame Denſity with the outward Air) or the Water, if it is ſo high, puſhing the Valve upwards, which is faſten'd to the cylindrick Wood only in the Place (*e*,) riſes

Plate 14. Fig. 6.

riſes on the oppoſite Side, and then the Air or Water will freely go upwards thro' the Hole E. But when the Bucket is moved upwards, then the outward Air, (or the Water if it is ſo high) preſſing upon the Valve, will ſhut the Hole E, and hinder the Air or Water from going thro' it. Lect. VIII.

The Uſe of the two Iron Plates, the one above and the other below the Leather, is to ſuſtain the Preſſure of the Water, which otherwiſe would bend the Leathers. This ſort of Buckets will be ſufficient for ſmall or ſhort Pumps, being beſides the cheapeſt of all. But if it be a very large Pump, then the Way will be to make the Bucket after the following manner.

There is a hollow Piece of Braſs S S, (*Fig.* 7.) almoſt equal at Top to the Bore of the Barrel, but ſmaller at the Bottom, (making therefore a hollow truncated Cone,) having at its Top, (ſhewn in *Fig.* 8. alſo) the Braſs Bar O O, and at the Bottom (*Fig.* 9.) the two Notches (*h h*,) to receive the Ends of another Braſs Bar R R, (*Fig.* 10.) or *h* K *h* (*Fig.* 7.) of the ſame Figure as this at the Top. Plate 14. Fig. 7. Plate 14. Fig. 8, 9, and 10.

There is a Leathern Ring L L, (*Fig.* 7. and 10.) which goes quite round the Braſs Piece, and is faſten'd to it at its lower Part, by means of the Iron Ring I I, which being almoſt at the Bottom of the Braſs Piece, is not ſo large as its Top, and conſequently touches not the Sides of the Barrel; this Leathern Ring ought to go a little higher than the Croſs-Piece at Bottom. The 8th and 9th Figures ſhew the Top and the Bottom of the Cone S S. Plate 14. Fig. 7. and 10.

The Valve conſiſts of a Piece of Leather V V, (*Fig.* 11.) almoſt equal to the Top of the Braſs Piece S S, covered by two Iron Plates D D, (*Fig.* 12.) of the ſame Bigneſs as the Leather itſelf, and having under it two Iron Plates E E, (*Fig.* 13.) a little ſmaller than the Bore of the Braſs Piece at its Top; theſe Iron Plates and the Leathers are faſten'd together by means of Screws which are here mark'd by black Points. Plate. 14. Fig. 11, 12, and 13.

This Valve muſt be applied to the Top of the Braſs Piece or Box, ſo that the Braſs Bar O O (*Fig.* 8.) be between the two Iron Plates E E, under the Leather. Plate 14. Fig. 8.

The whole is faſten'd together by means of an Iron Piece P P G, (*Fig.* 14.) whoſe lower Part G goes thro' the Holes in the Middle of the Valve, and the two Braſs Rods O O and R R, ſo that its upper Part P P getting between the two upper Iron Plates D D of the Valve, preſſes upon the Leather U V, and makes it apply itſelf cloſe to the Braſs Bar O O. Plate 14. Fig. 14.

The Iron Rod P P G ought to have two Holes, one at the Bottom juſt under the Braſs Rod R R, to hold it cloſe by means of a Pin or Key T, and another at its Top to faſten it to another Iron Rod N N, (*Fig.* 15.) which Plate 14. Fig. 15.

Lect. VIII. which is continued quite to the Top of the Pump, in order to give the Motion to the Bucket.

It is evident that the Bucket being made after this manner, the Leather of the Valve being fasten'd to the Brass Piece but in one Line, (*viz.* over the Bar OO) will be lifted up on both sides, when the Bucket goes down, and the Flaps will apply themselves close to the Top of the Brass Box when the Bucket goes up. See *Fig.* 16.

Plate 14. Fig. 16.

The chief Advantages of this kind of Buckets are, that they give the freest Passage to the Water; that is, have the least Friction possible, as they touch the Barrel but at the upper End of the Brass Box; and that the Sand or Gravel which commonly is mix'd with the Water, cannot get between the Bucket and the Barrel, by reason of the Leathern Ring being higher than the Brass Tube, which if it did happen would cause a deal of Friction, and soon spoil the Barrel: but after this Way all the Sand will fall down upon the Valves, from whence it can easily be taken off. Moreover, if by any Accident the Motion of one Side of the Valve were hindred, the other would serve till it were mended.

Plate 14. Fig. 17.

18. The most usual Way of making the Valves in the Pipes, is to have a hollow Brass Box A A, whose outward Side is just equal to the Bore of the Pipe, so that when it is fixed in it, it does not let any thing get between them. Its Top C C ought to be bored or turned obliquely within, that is conically, and there must be at its Bottom a Bar F F, which has a Hole I in its Middle. There is another Brass Piece B B D, put thro' the Hole I, and whose Top fits just to the oblique Top C C of the Brass Box; both being made conical, and well ground together. The Shank B B D ought to move freely thro' the Hole I, but it must be hinder'd from going too high, by means of a Nut D, which is screw'd at the Bottom, and pinn'd under, that it may not undo; sometimes a Piece of Plate riveted will serve.

Then it is evident that when the Water goes up thro' the Pipe E E, and the Box A A, it pushes up the Brass Piece B B; which as it is pushed down by the Weight of incumbent Water, shuts the Hole of the Brass Box A A, and hinders the Water from going down.

There is an Inconvenience in this kind of Valves, *viz.* that the Pipe ought to be widen'd at the Top of them at G G; or else the Water which is obliged to go between the Valve B B, and the Sides of the Pipe, would not have a free Passage, and consequently would by its great Velocity break the Pipes in that place, if they were not extremely strong.

* Ann. 5.

The best way of making the Valves * in the Pipes, is to make 'em like the second kind of Valves in the Buckets, which I explained before: only with

with this Difference, that the Box ought to be a perfect hollow Cylinder; and that it will not want the Iron Rod at the Top. Lect. VIII.

In whatever manner the Valves are made, the Box ought to be ſolder'd to the Pipes, if the Pipes be of any Metal; but if the Pipes are of Wood, then the Box muſt only be forced into them; and then it is convenient to have an Iron Ring *k*, to draw 'em out if it is neceſſary. *Fig.* 17. Plate 14. Fig. 17.

The Barrel ſhould be made of Braſs, Copper, Pot-Metal, (made of Lead and Copper) hard Metal made of Lead and Tin, or of hard Lead, that it may be ſmooth, in order to apply cloſe to the Piſton; Wood is only uſed for Cheapneſs.

19. If it were required to make Water go up the oblique Pipe B C, (*Fig.* 18.) by means of the Pump *a* D, then the Top D of the Pump muſt be ſhut, to hinder the Water from going thro' it, but at the ſame time it muſt allow a free Paſſage for the Iron Rod which gives the motion to the Bucket. Plate 14. Fig. 18.

The Way of doing it, is to have a Braſs Plate A A (*Fig.* 19.) larger than the Pipe, and ſcrew'd at its Top. The ſaid Braſs Plate muſt have a Hole B, (*Fig.* 20.) to receive the Screw E of a Braſs Box D D C C, (*Fig.* 21.) This Braſs Box is made of two Pieces D D and C C, (*Fig.* 22, and 23.) which can be ſcrew'd together at *f f*. It is made hollow in the Inſide, and is fixed with ſeveral oil'd Leathers applied to one another, and having each of them a Hole in the Middle, of the ſame Bigneſs as the Iron Rod. There muſt be Holes equal and correſpondent to them at the Top and at the Bottom of the Braſs Box. Then it is evident, that if it be put together, and the Iron Rod goes thro' the Holes, then if the Pump plays, the Water being hindred by the Leathers in the Box from going out at the Top of the Barrel, will go up the oblique Pipe B C, where it may paſs through a Valve V to ſtop its Return. See *Fig.* 18. Plate 14. Fig. 19. Plate 14. Fig. 20, 21, 22, 23.

N. B. Sometimes there is a large Veſſel or Cylinder of Lead L L C C, (*Fig.* 21.) to be kept full of Water, that the Leathers of the Collar may be always kept moiſt. Such a Collar and Box is called by the Workmen in the North a *Jack-Head*. Plate 14. Fig. 21.

The lifting Pump conſiſts of a Barrel A B B, opened at the lower End B B, and having a Valve H at its Top, where it communicates with the Pipe C. There is an inverted Bucket G, which moves up and down in the Barrel by means of an Iron Rod D E F E. The Bucket has a Valve I at its Top, and has the Hole at its Side, which goes quite to the Top, and thro' on the Inſide. Plate 14. Fig. 24.

If then the Barrel be put in Water up to W W, it is evident that when the Bucket is down, the Water will riſe to that Level in the Barrel, thro' the Hole in the Bucket. But when the Bucket moves upwards, the Preſſure

Lect. VIII. Preſſure of the Water in the Barrel ſhuts the Valve I, and opens the Valve H, and conſequently it riſes in the Pipe C, from which it never can come down again, by reaſon of the Valve H, ſo that it can riſe to any Height in the ſaid Pipe.

Plate 14. Fig. 25, 26.

20. THERE are two Sorts of Buckets uſed in the Lifting Pump, and the Conſtruction of the firſt is this; *a* A is a cylindrick Piece of Braſs a little leſs than the Bore of the Barrel, and cut round at C to receive a Leathern Ring, which when it is faſtned about it, makes it juſt equal to the Bore of the Barrel, ſo as to hinder any Air or Water from getting between. The cylindrick Piece of Braſs muſt have a Hole B quite through it, and is hollow like a Tube from the Hole B up to the Top.

THERE is at the Top a Valve V, made after the ſame way as thoſe in the Buckets of the Sucking Pump; the lower Part D of the Bucket ought to have a Screw, or any other Contrivance, to faſten it to the Iron Rod, which gives the Motion to it.

THE ſecond Kind of Buckets differs from this but in the Leathers, which in this are fixed in the following manner.

Plate 14. Fig. 27, 28, and 29.

THE cylindrick Braſs Piece is divided into two Pieces, A A and F F, (*Fig.* 27. and 28.) of which the upper one F F is a little leſs in Diameter than the other; theſe two Pieces can be joined together by means of a Screw. There is a Leathern Piece L L, (*Fig.* 29.) which ought to be applied between them, when they are ſeparated, and which being larger than either of them, applies itſelf to the upper one F F, (becauſe that Piece is the ſmalleſt) when they are ſcrew'd together, ſo as to make it equal to the Bore of the Barrel, and the lower Pipe A A being a little larger in Diameter, hinders the Leather from turning itſelf when it is in the Barrel.

THE Advantage of this Sort of Buckets above the firſt is, that it may be fitted with thin Leathers, which are a great deal ſmoother than thick ones: Beſides, it has no Friction at all when the Bucket goes down in the Barrel. The lower End of the Barrel ought to be a little wider and taper, that the Bucket may the eaſier be put into it.

Plate 14. Fig. 30.

21. THE forcing Pump conſiſts of a Barrel A B C, (*Fig.* 30.) in which there is a Forcer I, (or Piſton without a Valve) which moves up and down in it. The Barrel communicates with two Pipes, the one called a Sucking Pipe B C, which goes down into the Well, and the other called a Forcing Pipe F G, which goes upwards. There are two Valves, the one D, at any place of the Pipe B C, and the other E, in the Pipe F G, which both let the Water go up, and hinder it from going down; then when the Forcer is moved upwards as it rarefies the Air in the Pipe B C, (for the Valve E hinders the outward Air, which preſſes upon it, from

going

going thro',) the Water rises in it, till after several Strokes it comes to the Lect. VIII.
Forcer; then at every time the Forcer goes down, the Water that is pressed downwards, being hindred from going thro' the Valve D, opens the Valve E, and goes up the Pipe F G. When the Forcer goes up again, then the Water in the Pipe F G shuts by its Pressure the Valve E, and consequently the Water in the Well rises up the Pipe E B, and the same happens at every Motion of the Forcer. Plate 14. Fig 30.

It is to be observed in the Forcing-Pump, that the nearer the Forcer comes to the Well, the better it is, for the same Reason as in the Sucking-Pump.

There are several Ways of making the Forcers.

The most common of all consists of a Brass Cylinder, a very little less in Diameter than the Bore of the Barrel, (*Fig*. 31.) at the Top B and at the Bottom D, and turn'd less still at the Middle C C, in order to let in a Leathern Ring or Collar E E, *Fig*. 32. (made of a thick Leather, put round the Brass Cylinder,) which makes it just equal to the Bore of the Barrel, so as to fit it quite when it is put into it. Plate 14. Fig. 31, 32.

The second Sort of Forcers consists of three Brass Cylinders A, B, C, (*Fig*. 33, 34, and 35.) which can be screw'd together. The middle one B, ought to be almost equal in Diameter to the Bore of the Pipe, so as to slide in it without any Friction. The upper A and the lower C must be a little less, and equal to one another. There are two Leathers D and E, (*Fig*. 36, and 37.) which must be put between them when they are unscrew'd. Then it is evident that if the Cylinders be screw'd together, and the Leathers, (which ought to be a little bigger than the Brass Cylinders) apply themselves folding upwards round the upper A, and downwards round the lower C, they will become just equal to the Bore of the Barrel; and consequently they will hinder any Air from getting thro' the Sides of the Forcer, when it moves up and down in the Barrel; the Use of the middle Brass Cylinder B, is to hinder the Leathers from turning themselves back by the Motion. This kind of Forcers has, above the aforementioned one, the Advantage of having a great deal less Friction; and besides, as the Leathers which are applied to it, may be thin ones, they are much smoother than thick ones, which are used in the other. The Objection which is commonly made against thin Leathers, is, that it is a great Difficulty to get them into the Barrel, by reason of the Resistance of the lower Leather. This Inconvenience may be avoided by means of a short hollow Cylinder of Wood, or any Metal, equal in Bore to the Barrel, and which can be applied close to its Top. If the lower Part of the Forcer be unscrew'd, the upper and the middle ones can be put into the before-mentioned hollow Cylinder, without any Difficulty; and Plate 14. Fig. 33, 34, 35. Plate 14. Fig. 36, 37. Plate 14. Fig. 38.

 if

Lect. VIII. if then the lower with its Leather be ſcrew'd on again, and the hollow Cylinder be applied to the Top of the Barrel, as they both are of an equal Bore, the Forcer can be brought down into the Barrel, without any Reſiſtance.

Plate 14. Fig. 39. 22. The beſt way of making Forcers, is to have a Plunger, or ſolid Braſs Cylinder A, (*Fig.* 39.) equal in Length to the Barrel, and a little leſs in Diameter than the Bore, ſo that it can move freely in it without any Friction; there muſt be two hollow ſhort Braſs Cylinders, or rather Rings, CC, DD, (*Fig.* 40, and 41.) at the Top of the Barrel F, which can be ſcrew'd together. The upper one CC muſt be equal in Bore to it, and the lower D a little leſs. There are two Leathers F G, (*Fig.* 43, and 44.) both having in the Middle a leſs Hole than the Bore of the Pipe. The one muſt be applied between the Barrel and the Ring D, and the other between the ſame D, and the upper one C, and the whole muſt be ſcrew'd together. Then if the ſolid Cylinder A, be put into it, and moved up and down, it is evident that the two before-mentioned Leathers, which are applied the one to the Barrel, and the other to the Inſide of the hollow Cylinder C, will hinder any Air from getting between them and the ſolid Cylinder A. *N. B.* If the Bore of the Barrel be much bigger than the Diameter of the Cylinder, a third Ring like CC muſt be alſo fixed under DD, for the lower Leather to apply to.

Plate 14. Fig. 40, 41, 42.

Fig. 43, 44.

The Advantage of this kind of Forcers, is, that they have no other Friction, but at the Top of the Barrel, and that the Inſide of the Barrel need not to be ſmooth, as in other kinds of Pumps, but only the Outſide of the Forcer A muſt be turn'd true and poliſh'd, which can be done a great deal eaſier.

Fig. 39.

The lower Part of the Forcer A, muſt be turn'd a little conical, that it may be brought into the Barrel, without any Reſiſtance of the upper Leather of the above-mentioned Collar or Jack-Head.

If it be deſired to know to what Height Water will riſe in any Pump at every Stroke of the Piſton, it can be found by Algebra; provided the Play or Stroke of the Piſton, and its Diſtance from the Surface of the Water, be known. See the Notes †.

† Ann. 6.

To illuſtrate this yet further, I have contrived all theſe ſeveral Pumps with the working Barrels, the firſt Part of the Conduct, and the Air-Veſſels, all of Glaſs, to make the Motion of the Piſtons (whether Buckets or Forcers) viſible, as well as the Riſe and Fall of the Valves, and the Action of the Air upon the Water, as it drives it, by expanding itſelf after it has been compreſſed. But as theſe Machines are chiefly intended to make every thing plain and viſible at my Courſes of Experimental Philo-

ſophy,

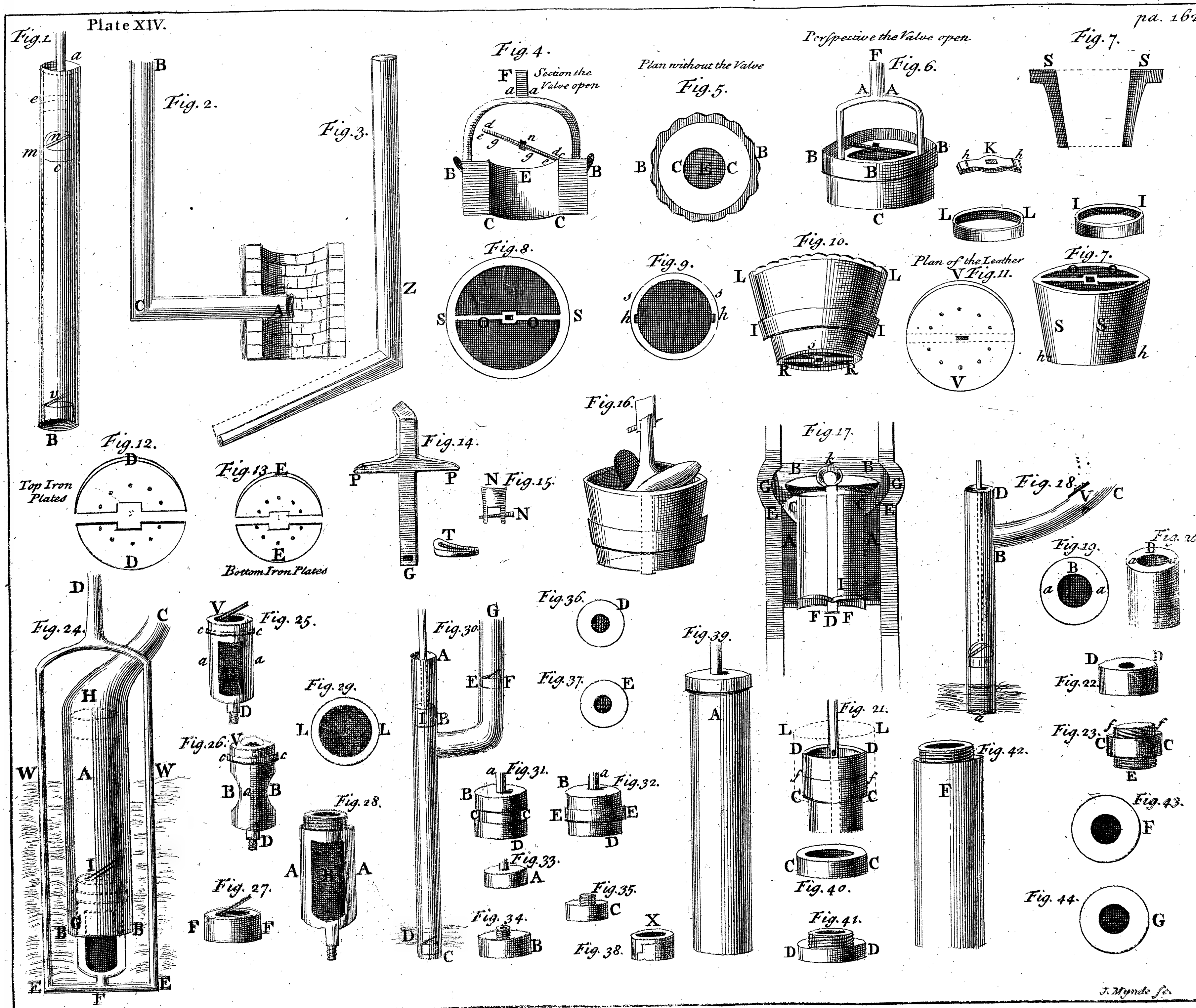


Plate XIV.
pa. 162.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4. Section the Valve open
Plan without the Valve
Fig. 5.
Perspective the Valve open
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Plan of the Leather
Fig. 11.
Fig. 12.
Top Iron Plates
Fig. 13
Bottom Iron Plates
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.
Fig. 23.
Fig. 24.
Fig. 25.
Fig. 26.
Fig. 27.
Fig. 28.
Fig. 29.
Fig. 30.
Fig. 31.
Fig. 32.
Fig. 33.
Fig. 34.
Fig. 35.
Fig. 36.
Fig. 37.
Fig. 38.
Fig. 39.
Fig. 40.
Fig. 41.
Fig. 42.
Fig. 43.
Fig. 44.
J. Mynde sc.

ſophy, we are not to expect a Scale to the Draught, or the juſt Proportions of the Valves, and of the Sucking and Forcing Pipes, &c. neither need we give any ample Deſcription of theſe working Models, the Inſpection of the Draughts, and what we have ſaid already, being ſufficient. Lect. VIII.

Plate 15. *Fig.* 1, 2, 3, 4, 5.

23. The firſt Figure repreſents the Sucking Pump. The Lump or Foot of Wood G has fixed to it a Braſs Frame, conſiſting of two Rulers or long Plates, ſuch as G C, (repreſented here as broken off, to ſhew the Hind part; and viſible only at three Places, as G, E and C,) with two Rings having Ears coming out horizontally on their Sides at A B, and D F. The Glaſs Pump-Barrel C O, open at Bottom and cloſe at Top, with its Braſs-Work at O E and P C, is let into the Rings of the Frame above-mentioned as it ſtands up. The Lifting, or Piſton-moving Rods, are let down thro' the Holes in the Ears A, B, D, F, and are fixed at bottom by the Screws K L, to the Croſs-Plate K M L, which has at its Middle M a perpendicular Rod M N, bearing the inverted Piſton N with its Valve *n*. From P the Braſs-Work of the Top of the Glaſs-Barrel, goes an Elbow made of two Pieces B, Q, one of which Q has at Top the Valve *q*. The Glaſs Conduct-Pipe T R, with its Braſs-Work at T R, and its Ajutage or Spouting-Pipe at Z, is ſcrew'd on upon Q; then the whole Machine, Pump, Rods, Frame and Foot is plunged almoſt as far as C, into the Water of the Glaſs-Jar V X Y W, repreſenting a Well or Ciſtern in which a Lifting-Pump works: the Foot G reſting upon the Bottom of the Glaſs. Plate 15. Fig. 1, 2, 3, 4, and 5.

To work this Pump, take hold of the Ring fixed to the Plate H I, and puſhing downwards till M comes to G, as the Piſton comes down, the Water will riſe thro' it, and come upwards thro' the Valve at *n*; then pulling the Rods up again, the Valve ſhutting, the Piſton will puſh the Water before it, which will go along C P B Q T, and lifting up the Valve *q*, riſe as far as S in the Conduct-Pipe. Putting down the Rods again, the Valve *q* will ſhut and retain all the Water that is above it, whilſt the Piſton or inverted Bucket N fetches another Quantity of Water, which lifted up will raiſe the Valve *q* again, and go up towards R, till after a few Strokes the Water will come out at Z. In this Caſe, whether the Water ſpouts out at Z, or is conducted in a long Pipe to be delivered at a great Diſtance, it will come by Intervals, iſſuing out only when the Piſton N is coming up. But you may have a conſtant Stream of Water, by turning the Piece T R into an Air-Veſſel, which is done thus: Having ſcrew'd off the Head at R, to the Under-Side of Z ſcrew the Glaſs-Pipe R *q*; then ſcrew the Head on again before any Water be in the Conduct T R,

Lect. VIII. and make all right. The next time that the Piston coming up pushes Water thro' the Valve q, at the same time that some of it goes thro' the Glass-Pipe and out at Z, some will go up into the Cavity q S R, round about the Glass-Pipe, and condense the Air which filled the Space q R into the Space S R; and when the Piston goes down again to fetch more Water, the Air between R and S expanding itself again, will continue the stream out at Z, which would have ceased without it till the next Lift of the Piston.

N. B. *There is not more Water raised in the same time by the Use of an Air-Vessel, than without, which has made some People believe that an Air-Vessel was of no advantage in Engines. But there is a considerable Advantage, especially where Engines work fast. First, there is much less Strain upon the Conduct-Pipes, if the Water goes to a great Distance. Suppose, for example, the Engine raises a Gallon at a Stroke, and goes 30 Strokes in a Minute; every other Second the whole Water stands still, and then the whole Quantity of it must be put in Motion a-new, every time the Valve* q *(called the Forcing Valve) opens, which is a great Shock to the Pipes. But if you use an Air-Vessel, the Water is continually running, which it does with only half the Velocity; because no greater Quantity of Water in the whole time, when continuous, runs thro', than did in half the time when discontinuous: And it is plain, from what we have before shewn, that the Impression on the Pipes is quadruple, when the Velocity is double.*

In the Use of Engines to put out Fires, which have no Air-Vessels, like the Dutch *Engines, or old Parish Engines, a great deal of Water is lost at the Beginning and End of the Jet or Spouting of the Water; whereas not one Drop is lost when the Engine has an Air-Vessel sufficiently large. Besides, if you aim at any Place by turning the Spouting-Pipe to it, you cannot direct the Water to it, and strike it, near so soon, when there is an Air-Vessel as when there is not.*

Plate 15. Fig. 2. 24. The second Figure shews a Sucking Pump, where S represents the Sucking-Pipe, and V its Valve; D P is the Pump-Barrel here made of Glass; B is the Piston or moveable Bucket with its Valve W, which is moved up and down by its Handle A. When B rises, it takes off the Pressure of the Air from its Valve W. Whereupon the Weight of the Atmosphere on the Water in the Well pushes up through S, then through the Valve V towards the Bucket B. Pushing the Bucket down again, the Water, having shut the Valve V, comes up through the Bucket, opening

opening the Valve W; then it is lifted by the Bucket into the Ciſtern CD, from whence it runs out thro' the Noſe or Spout P *p* Q. Lect. VIII.

25. THE third Sort of Pump, (*Fig.* 3.) is the Sucking and Lifting Pump. Plate 15. Fig. 3.

THE Sucking Pump is commonly uſed in a Yard or Area near a Houſe, to draw Water out of a Well for the Uſes of the lower Part of the Houſe; but if you join to its Noſe a Pipe of Conduct, ſhutting up the Noſe with a Cock, and putting a Collar of Leathers on the Top of the Pump, which admits only the Rod of the Piſton, and lets out no Water; the Water upon occaſion, (as in Caſe of Fire) may be conveyed to the Top or any Part of the Houſe. If the Conduct is carried along in the Corner of a Stair-Caſe; by ſcrewing on a Leather Pipe at every Floor, the Water may be carried into any Room, ſo as to ſpout againſt any ſudden Fire. There will, at that time, be only ſo much more Labour required of the Perſons employed in pumping, as the Water is raiſed higher than the Noſe of the Pump. At other times, the Cock, which we have ſuppoſed at Q, being opened, the Pump ſerves for its common Uſes, and goes as eaſy as if it had none of the Additions above-mentioned.

EVERY thing in this Figure is marked with the ſame Letters as the laſt; only here is added the Collar of Leathers C, the Leathern Pipe L, and the Conduct-Pipe T R, with its forcing Valve F.

26. THE fourth Figure repreſents the Forcing Pump, where the Glaſs Tube repreſenting the Barrel, is now inverted with the Communication-Piece at Bottom. The Piſton B B has no Valve, but Leathers looking upwards and downwards, above and below the guiding Plate B B, as has been already deſcribed. By the Handle A, pull up B B, and the Water will come up the Pipe S, thro' the Sucking Valve P, for the Reaſons already deſcribed: thence being puſhed down again by the Piſton B B, it will go thro' P *p* Q T, and the Forcing Valve F, Part up the Pipe F R, where it will immediately ſpout out, and Part will riſe round the Tube up to *a a*, where it will condenſe the Air, which expanding itſelf again, will continue the Jet whilſt the Piſton is riſing to bring the Water out of the Well. *N. B.* The Cup C D is to keep a little Water in, that the Leathers of the Piſton may be always moiſt and tight. Plate 15. Fig. 4.

27. THE fifth Figure repreſents the Pump with the Plunger, ſuch as we have already deſcribed *Numb.* 22. of this Lecture; ſo that we ſhall need to ſay the leſs about it here. B B is a Braſs Plunger or ſolid Cylinder, with its double Rod A, on which are ſlipped the Cheeſes, or Leaden Plate 15. Fig. 5.

flat

Lect. VIII. flat Weights, E F F E to add to the Weight of the Plunger upon occaſion; C D O is the Jack-Head and its Cup, to be further deſcribed, *Fig.* 6. Here the Conduct F Z, which may be ſuppoſed of any Length, and to run to any Diſtance, has a Side-Pipe G, to which is joined the Air-Veſſel G I K H, which needs no farther Deſcription than a Sight of the Figure, which ſhews how the Water riſing up towards I H condenſes the Air above it towards K, which re-acts upon the Water to drive it into the Pipes in the Intervals of the Strokes from the Engine.

Plate 15. Fig. 6. 28. The ſixth Figure is a Section of the Jack-Head, to ſhew its Parts ſtill plainer.

C C C, that Part of the Plunger which is embraced by the Jack-Head.

G *g g* G, the Guiding-Plate, whoſe Hole is but juſt big enough for the Plunger to ſlip thro'.

V *u u* V, the upper Plate, whoſe Hole is wide enough for the Leathers *d g u*, *d g u* to turn up between the Plate and the Plunger.

L A A L is the Return of the Pipe, to which all the Plates of the Jack-Head are joined by the Screws *s s*, leaving room enough for the Leathers *e g* H, *e g* H to turn down and apply to the Plunger.

B C H, B C H, ſhews the Space between the Plunger and the Barrel.

Plate 15. Fig. 7. 29. The ſeventh Figure repreſents the Section of a Pump with the Plunger working thro' the Jack-Head, where the Pipes, Valves, Plunger and Rod, are repreſented by the ſame Letters as in the foregoing Figures; only here is to be obſerved, that in the Section of the Cup, P C D is a little Pipe with a Cock at C, and a Valve at D, to diſcharge the Air between the Plunger and the Barrel, till the Water is come up quite to the Jack-Head.

N. B. *In making the Experiments with the Glaſs Models of the Pumps, there is generally put on a Spout that turns downwards,* (Fig. 1.) *to prevent the Perſons preſent from being wet.*

End of the Eighth Lecture.

ANNO-

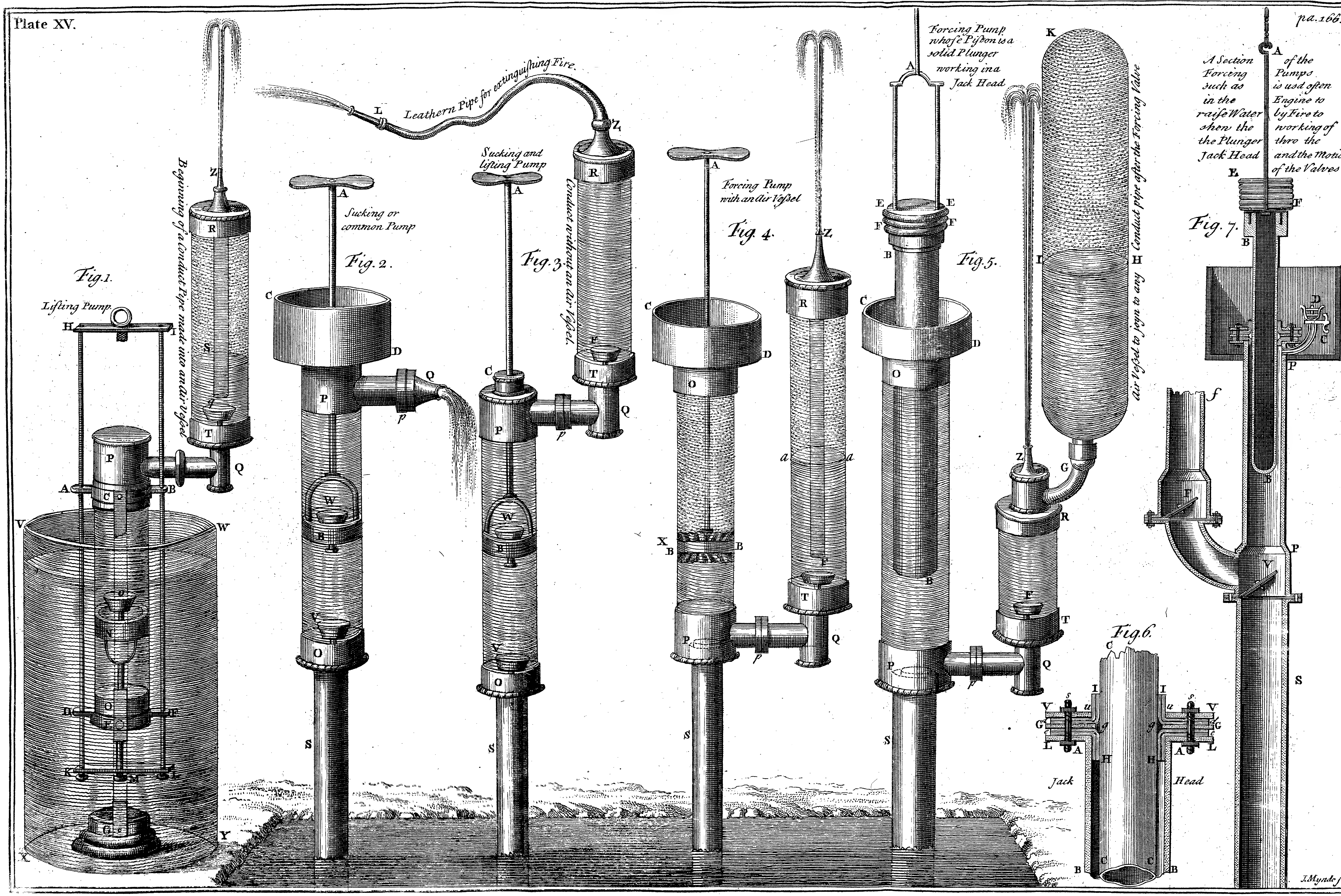


Fig. 1.
Lifting Pump.
Beginning of a Conduct Pipe made into an Air Vessel
Fig. 2.
Sucking or common Pump
Leathern Pipe for extinguishing Fire.
Fig. 3.
Sucking and lifting Pump
Conduct without an Air Vessel.
Fig. 4.
Forcing Pump with an Air Vessel
Fig. 5.
Forcing Pump whose Piston is a solid Plunger working in a Jack Head
Air Vessel to join to any Conduct pipe after the Forcing Valve
Fig. 6.
Jack
Head
Fig. 7.
A Section of the Forcing Pumps such as is used often in the Engine to raise Water by Fire to shew the working of the Plunger thro the Jack Head and the Motion of the Valves

J. Mynde sc.

Annotations upon the Eighth Lecture.

1. [1.——*The Air has been suck'd out*, &c.——*short Leg——that Part which is above Water——as if the Orifice was at* G.]

A SYPHON may be so contriv'd, that there shall be no need of sucking out the Air; but only filling it with Water, or the Liquor that is to be decanted before you put it into the Vessel from which the Liquor is to run. Annotat. Lect. VIII.

Experiment 1. *Plate* 16. *Fig.* 1, 2, and 3. Plate 16. Fig. 1, 2, 3.

Take a Syphon of equal Legs turn'd up at the End of each Leg as E R F, *Fig.* 1. and having fill'd it with Water, the Columns of Water will balance each other without any Water running out: then plunge the two Ends E, F, of this Syphon, into the two Jars of Water A B and C D, *Fig.* 2. in the first of which the Water stands at S S, and lower in the Jar C D, (as at *s s*) the Water will immediately run from A B into C D, till, by falling in A B, and rising in C D, it settles at O P the same Level in both Jars. If Water be pour'd into the Jar C D up to C, it will run back into the Jar A B, till it comes up to S S in that Vessel, whilst it is got down to T in C D, or the Line S S T, shewing both Surfaces to be at the same Level. The same thing would have happen'd by holding the Jar A B so much below the Level of C D: and so the Water will run alternately from one Jar into the other, the two Legs becoming successively the *driving* or the *issuing* Leg; that is here, the *long* Leg, or *short* Leg; which shews, that the Length of the Legs is only to be reckon'd above the Liquor. So that when the Water is at S S in A B, and *s s* in C D, not E R, but M R, is the *short* Leg; and R N, not R D, the *long* Leg: consequently, if by holding the Jar A B lower than C D, the Surface S S be brought lower than *s s*, N R will be the *driving* or *short* Leg, and R E the *issuing* or *long* Leg.

To shew likewise that the Length of the Legs are to be estimated by their perpendicular Height, let L *l* be a level Line running thro' the upper Part of the Bend of the Syphon; L M and *l* N, Perpendiculars, let down from it to the Surfaces of the Water S S and *s s*, must be call'd the Lengths of the Legs M R and N R.

This will appear more evidently by *Fig.* 3. where inclining this Syphon when full, the Water will run out at E, when F is rais'd up, (and likewise at F, when E is rais'd up) for no other Reason, but because the equal Columns of Water in the equal Legs E L and F L, or the Legs themselves are made

Annotat. Lect. VIII. unequal in their perpendicular Height, L F becoming *l* F, and L E becoming L I.

2. [3.—*The Pressure of the Air the Cause of the Water being push'd up into the Syphon*, &c.] Here it may be objected, that Syphons will run *in vacuo*, and therefore that the Air is not concern'd in the Motion of Fluids thro' a Syphon: and indeed I have made the Experiment both with Water and Mercury; for having fill'd a Syphon, such as is represented in *Fig.* 1. successively with those Liquors, and suspended it by a Slip-Wire in the Receiver of an Air-Pump, over two small Jars containing Mercury to unequal Heights, (and Water, when Water was used in the Syphon) I exhausted the Air out of the Receiver, and then letting down the Syphon, so that its two Ends went into the Liquor in the Jars, the Liquor ran from the higher into the lower Vessel.

I also made an Experiment in the open Air, where the Mercury ran thro' a Syphon, whose Bend was more than 31 Inches above the lower Orifice of the short Leg of the Syphon.

Experiment 2. *Plate* 16. *Fig.* 4, 5, and 6.

I took a Glass Tube A B, *Fig.* 4. 33 Inches long, an Inch and an half in its outward, and an Inch and a quarter in its inward Diameter; and having cemented its lower End into a wooden Foot B N N, made heavy to stand fast, I cemented its upper End into an hollow Cylinder of Wood, *Fig.* 5. that had a large Slit cut in it at O P, to be fill'd up by a sliding Piece L, after having let into the said Slit the Bend of a Glass Syphon, having one Leg in the Tube, and the other without it. The Syphon is represented by S L *s*, *Fig.* 4. and *Fig.* 6. The Height from S to L was 32 Inches, and from L to *s* 35 Inches. Having put the Leg S of the Syphon into the Tube, and rested its Bend at L, I made it fast and all tight by Cement about the Bend of the Tube, after the Piece L (of *Fig.* 5.) had been let into the Slit to fill it up. Things being thus prepar'd, I fill'd the great Tube with Mercury up to M M, (see *Fig.* 4.) then having plac'd a Jar under *s*, to receive the issuing Mercury, I push'd in a small Stick D E by the Side of the Syphon into the great Tube, to raise the Mercury to *l* L, which set the Syphon a running, and that running continu'd till the Surface of the Mercury came down to S in the great Tube. *Fig.* 4. represents the Section, and *Fig.* 6. the Perspective of the Machine. Notwithstanding these Experiments, the Air is the Cause of the running of Liquors in Syphons; for, that it ran *in vacuo*, was only owing to the Attraction of Cohesion, which acts for a small Height; because the Experiment will not succeed *in vacuo*, if the Syphon used for Mercury has its Bend six Inches higher than the Orifice of the short Leg, and if the Bend of the Syphon for Water be two or three Feet high. Neither will the last mention'd Experiment answer, if the Bend of the Syphon be 40 Inches high: and in all the Experiments the Bores of the Syphons must be very small.

Plate

Annotat. Lect. VIII.

Plate 16. *Fig.* 12.

Plate 16. Fig. 12.

ANN. 3. [6.——*This Consideration of Monf.* Belidor's *is of great use in making Pumps,* &c.——*refer*——*to the Notes upon that Subject.*] Having well examin'd what Mr. *Belidor* has taken notice of, in relation to the 4th, 5th, and 6th *Figures* of *Plate* 13, we will apply it to a sucking Pump, and then give Mr. *Belidor*'s Calculation of it.

LET A B F G S D C be an inverted Syphon with equal Legs. Let A B D C be the driving Leg, fill'd with Water as far as S F, the Bottom of the issuing Leg: if S F, from being stopp'd, be suddenly unstopp'd, the Water will begin to rise towards G with all the Velocity belonging to an Height as A D, (estimated by the square Root of it) but that Velocity will diminish as the Water comes down from A C, till it stands at a Level in both Legs. If the driving Leg A D was kept full, the Water would rise up to G in the issuing Leg G S, and run out continually, if A C be ever so little higher than G. Supposing still, that the driving Leg A D is kept full, and the Stop be remov'd from S F to Q R, or that a moveable Piston is held at Q; upon removing this Piston upwards towards *b c*, the Water at Q will rise up, not with a Velocity proportionable to the Root of A O, (or of $\sqrt{AD - SQ}$) but with a Velocity proportionable to $\sqrt{AD} - \sqrt{SQ}$, which is much less; so that if the Piston be drawn upwards from Q with the same Velocity that the Water would have at S F, (if the Piston had been pull'd up from that Place) the Water will not rise fast enough to follow it, and touch it continually, but leave a Space between, till the Piston coming down meets it again.

NOW let us suppose the issuing Leg G F to be chang'd into the Pipe of a sucking Pump G L, going into the Water of a Well, Pond or River, whose Surface is S M; then A D will be no longer a Column of Water, as a Leg of a Syphon; but the Weight of the Atmosphere, which we will for ease of Calculation still call a Column of Water 33 Feet high; Q R the Level, or Place of the Piston when at lowest, and Q *b* the Height of its Play: S Q = O P, the Distance of the Piston above the Surface of the Water in the Well = 7,29 Feet, and A N = 25,71 Feet. I say; *that in this Case the Piston rising from* Q R *with the same Velocity, that would be proper for it to rise from* S M, *tho' with the same Length of Stroke, the same number of Strokes in a Minute, and loaded with the same Weight of Atmosphere, would not raise so much Water*; as will be easily shewn. Since 5,7 is the Root of A D (= 33) we may consider that Number as proportional to the Velocity of the Piston working at S F, which is the Velocity with which the Water can follow. But since the Velocity of the Water at Q R, is only proportionable to the Number 3, (because $\sqrt{33} - \sqrt{7,29} = 5,7 - 2,7 = 3$) the Water will only follow the Piston, when it moves upwards from Q with a Velocity which is to that of the Piston, as 3 to 5,7; so that the upper Part of the Stroke of the Piston will be ineffectual, there being a void Space between the Water and the Piston, and likewise some Part of the descending Stroke lost, till the Piston comes down to

 the

Annotat. Lect. VIII. the Water to press it up thro' its Valve: and this will happen every time that the Piston having descended its full Stroke, rises up from Q R. I have observ'd several Pumps at Sea, which had this Defect, especially when they were new. As the Men press'd down the Handle with which they pump'd, if they did not hold down the Handle some time, it would fly up again, and the Piston come down near half its Stroke: in this case the Water rose slower than the Piston, not only for the Reasons already given, but also because the sucking Pipe in those Pumps is generally made much narrower than the Barrel, or the Part where the Bucket or Piston works. But the Sailors think this an Excellency in their Pumps, and say upon that occasion, that the *Pump speaks*, which is only a sign that the Pump is tight, and not that it raises more Water than if it went easier. If several Pumps move by any steady Power, such as Water, Wind, or Horses, and work by Regulators, the Defect is not immediately seen, but found by the too small Quantity of Water rais'd. In Machines one may also give the Pistons too small a Velocity, so that the Water, from the Pressure of the Atmosphere, shall receive a greater Velocity, which will likewise diminish the Quantity of Water to be rais'd.

I have here translated from Monf. Belidor, (Architecture Hydraulique, Liv. 3. Ch. 3. Page 83.) *his Manner of applying this to the Theory of sucking Pumps. In which I have not reduc'd his* French *to* English *Measures, to avoid Fractions; and because, when any Problem is solv'd by his Method, you only need at last to increase the number of Feet and Inches* $\frac{1}{16}$, *because* 15 French *Feet or Inches are equal to* 16 English *Feet or Inches, in round Numbers.*

He supposes the Pistons so fix'd to a Machine, as to have a confin'd Stroke and Velocity in their working; and goes on thus, beginning from the Consideration of a Syphon.

"Making use of a Syphon, whose first, (or driving Leg) is always kept full of Water; and the second, (or issuing Leg) only up to the Height Q R, because it is stopp'd by a Piston P, sustain'd by the Power T; I say, that if that Power T raises that Piston from R to *c*, with a Velocity always uniform, one of the following Cases will always happen.

Tho' the Water be not free, it will always endeavour, as it accompanies the Piston from R to *c*, to rise with all the different Velocities of which it is susceptible; but if in going up it is reduc'd to a Velocity less than that of the Piston, it will cease to follow it, and there will be a void Space between them, which will increase more and more, in proportion as the Velocity of the Water will become less than that of the Piston. This is the first Case.

In the second Case, if the least Velocity of the Water be much greater than that of the Piston, not only there will be no void Space between them, but on the contrary, during the time of the Rise of the Piston, the Water would be able to fill a Space much larger than R Q *b c*.

Supposing each of the Legs of the Syphon to be 31 Feet high, the Weight of the Water of the first A D may be taken for that of the Atmosphere, and now considering one Pipe, as G L, plung'd in Water to the Level D M, it will happen, that if by any Cause whatever, this Pipe be depriv'd of Air, the Water will rise naturally in it from F to R, till it reaches the Piston, and

and act according to the Circumstances which belong to the one or the other of the two foregoing Cases; therefore the Pipe G L, may be look'd upon as a Sucking Pump which is uniform, and where the Height R c denotes the Stroke of the Piston. Annotat. Lect. VIII.

It follows from the first Case, that when in a Sucking Pump, the Velocity of the rising Water is less than that of the Piston, there is produced an empty Space which makes the Pump not give so much Water as it ought, tho' the Piston works at a much less Height than 31 Feet; because the Piston beginning to descend before the Pump-Barrel is full, at every Stroke you lose a Bulk of Water equal to that Void: And if this can happen even where the Diameter of the Sucking Pipe is equal to that of the Pump-Barrel, much sooner will it happen if the Sucking Pipe be made much smaller, because the Water rising thro' a less Passage, will be longer in filling the Pump-Barrel, and therefore sooner quit the Piston, and leave the greater void Space between.

On the contrary it follows from the second Case, that when the least Velocity of the Water, consider'd as uniform, shall be much greater than that of the Piston, there will be no void Space, and the Pump-Barrel may be made wider than the Sucking Pipe, without fearing that the Water should ever quit the Piston; and this will always happen, when *the Squares of the Diameters of the Piston, and of the Sucking Pipe, the least Velocity of the Water, and that of the Piston, are reciprocally proportional*; because then the inner Bulk of the Barrel will always be less than that of the Column of Water that is able to come into it, during the rise of the Piston: Now I judge that one can hardly give a Piston more Velocity than of 4 Foot in a Second, without exposing the Parts of the Engine to the Danger of being soon broken; and indeed I have never seen any Pump whose Piston did move so fast.

Let us call the Height of the Water equivalent to the Weight of the Atmosphere $=a$; the highest Elevation of the Piston above the Surface of the Water in the Well $=b$; $\sqrt{a}-\sqrt{b}$ will express the least Velocity of the Water which will rise into the Pump-Barrel, and not $\sqrt{a-b}$; which is very different, for we have $a+b-2\sqrt{ab}$ for the Fall capable to produce that Velocity, instead of $a-b$ according to the common Method; therefore, to have *that Fall, you must seek a mean Proportional between the Height of the Column of Water equivalent to the Weight of the Atmosphere, and that of the greatest Elevation of the Piston above the Water in the Well, double that Mean, and substract it from the Sum of the two Extremes.* Plate. 16. Fig. 12.

For Example, having $a=31$ Feet, we suppose $b=16$; thus the Mean between these two Numbers will be about 22 Feet 3 Inches, which being doubled, gives 44 Feet 6 Inches, which must be substracted from 47 Feet, the Sum of the said Numbers; and the Difference will be 2 Foot 6 Inches for the Fall; whereas, according to the common Notion, it would be 15 Foot. I leave the Reader to judge of what consequence in Practice may be a Difference arising from such an Error.

Annotat. Lect. VII.

To give a general Canon, that shall take in all that relates to the present Subject, we will call the least Velocity of the Water that rises in the Pump-Barrel V; u the Velocity of the Piston; D the Diameter of the Pump-Barrel; and d that of the Sucking-Pipe; and then we shall have $V : u :: DD : dd$, whence we deduce $Vdd = uDD$, which is an Equation made up only of four different Quantities, one of which is easy to find, the other three being given.

For Example, if we had a sucking Pump of six Inches Diameter, whose Piston according to the contrivance of the Machine, and the Velocity of the first Mover, should give 20 Strokes in a Minute, each a two-foot Stroke, spending as much Time in its Rise as in its Descent, that Piston will move 80 Foot in a Minute, and consequently will have a Velocity of 16 Foot in a Second.

I suppose, secondly, that the highest Elevation of the Piston above the lowest Water, is 18 Foot, and that we want to know what Diameter must be given to the sucking Pipe, that the Barrel may always be fill'd in the Time of the Rise of the Piston: In order to that, we must find what uniform Velocities in a Second, Falls of 31, and 18 Feet will give; which we shall find to be 43 and 32 Feet 9 Inches, whose Difference gives 10 Foot 3 Inches for the least Velocity of the Water.

We have then D=6 Inches, $u = 1\frac{1}{3}$ Foot, and V=10 Foot neglecting the Fraction, which being substituted in $\frac{\sqrt{uDD}}{V} = d$, gives 2 Inches 2 Lines and $\frac{1}{4}$ of a Line for the Diameter that you want, but which you must make at least of 2 Inches and 6 Lines, on account of the Friction.

When we know the Velocity of the Piston, the Diameter of the Pump-Barrel, and the Diameter of the sucking Pipe, we shall have $\frac{uDD}{dd} = V$ for the least Velocity of the Water, *which will be had by multiplying the Square of the Diameter of the Piston by the Velocity of the said Piston, and dividing the Product by the Square of the Diameter of the sucking Pipe.* Then you must take away that Velocity from that which is relative to the Column of Water equivalent to the Weight of the Atmosphere; the Difference will give the respective Velocity, for which we must only find the Fall, which will determine the highest Elevation of the Piston above the lowest Water of the Well, if its Level is apt to vary, and consequently the Situation of the Pump.

Suppose that the least Velocity of the Water be found to be 10 Foot 3 Inches; you must take it from 43, and the Difference will give 32 Feet 9 Inches for the respective Velocity; thus seeking a Fall capable of producing that Velocity, we shall have 18 Foot for the greatest Elevation of the Piston.

So likewise, when we know the Diameter of the Pump-Barrel, that of the sucking Pipe, and the greatest Elevation of the Piston, and consequently the least Velocity of the Water, one may determine what Velocity the Piston must have, that the Barrel of the Pump may fill; because then we have $\frac{Vdd}{DD} = u$, *which shews that we must multiply the least Velocity of the Water*

by

by the Square of the Diameter of the sucking Pipe, and divide the Product by the Square of the Diameter of the Piston. Annotat. Lect. VII.

Lastly, when we know the Velocity of the Piston, the Diameter of the sucking Pipe, and the highest Elevation of the Piston, or the least Velocity of the Water; one may also determine what must be the Diameter of the Pump-Barrel, because we have $\frac{\sqrt{Vdd}}{u}=D$, *which shews that we must multiply the Square of the Diameter of the sucking Pipe by the least Velocity of the Water, divide the Product by the Velocity of the Piston, and from that Quotient extract the Square Root.*

4. [10.—*Dr.* Jo. Atwell, *&c.*—*has in Phil. Trans. Numb.* 424, *&c.*] The ingenious Author, after making an Apology for what he intends to say upon the Nature of *Intermitting* and *Reciprocating Springs*, declaring that what he offers is rather as a Conjecture, than an absolute Solution of the Cause of these Phænomena, goes on with an Account of *Laywell* Spring in these Words——

"The Spring is situated at one end of the Town of *Brixam* near *Torbay* "in *Devonshire*, and is known by the Name of *Laywell*. It is a long Mile "distant from the Sea, upon the North Side of a Ridge of Hills, lying "between it and the Sea, and making a Turn or Angle near this Spring. "It is situated in the side of those Hills, near the Bottom, and seems to "have its Course from the South-West towards the North-East. There is a "constantly running Stream, which discharges it self near one Corner into a "Bason about eight Foot in length, and four Foot and a half in breadth; "the Outlet of which is at the farthest End from the Entrance of the "Stream, about three Foot wide, and of a sufficient Height. This I men-"tion, that a better Judgment may be made of the perpendicular Rise of the "Water in the Bason, at the time of the Flux or Increase of the Stream. "Upon the Outside of the Bason are three other Springs, which always "run, but with Streams subject to a like regular Increase and Decrease with the "former: They seem indeed only Branches of the former, or rather Chan-"nels discharging some Parts of the constantly running Water, which could "not empty itself all into the Bason; and therefore, when by means of the "Season, or Weather, Springs are large and high, upon the Flux or In-"crease of this Fountain, several other little Springs are said to break forth, "both in the Bottom of the Bason and without it; which disappear again "upon the Ebb or Decrease of the Fountain. All the constantly running "Streams put together, at the time that I saw them, were, I believe, more "than sufficient to drive an Overshot-Mill, and the Stream running into the "Bason might be one half of the whole. I had made a Journey purposely to "see it, in company with a Friend; when we came to the Fountain, we were "inform'd by a Man working just by the Bason, that the Spring had flow'd "and ebb'd about twenty times that Morning, but had ceas'd doing so about "half an Hour before we came. I observed the Stream running into the Bason

"for

Annotat. Lect. VIII. "for more than an Hour by my Watch, without perceiving the least Variation in it, or the least Alteration in the Height of the Surface of the Water in the Bason; which we could observe with great Nicety, by means of a broad Stone laid in a shelving Position in the Water. Thus disappointed, we were obliged to go and take some little Refreshment at our Inn, after which we intended to come back, and spend the rest of our Time by the Fountain before we returned home. They told us in the Town, that many had been disappointed in this manner, and the common People superstitiously imputed it to I know not what Influence, which the Presence of some People had over the Fountain. For which reason they advised, that in case it did not flow and ebb when we were both present, one of us should absent himself to try whether it would do so in the Presence of the other. Upon our Return to it, the Man who was still at work, told us, that it begun to flow and ebb about half an Hour after we went away, and had done so ten or twelve times in less than a Minute; we saw the Stream coming into the Bason, and likewise the others on the outside of the Bason begin to increase, and to flow with great Violence, upon which the Surface of the Water in the Bason rose an Inch and a quarter perpendicularly, in near the space of two Minutes; immediately after which, the Stream began to abate again to its ordinary Course; and in near two Minutes time the Surface was sunk down to its usual Height, where it remained two Minutes more; then it began to flow again as before, and in the space of twenty-six Minutes flow'd and ebb'd five Times; so that an Increase, Decrease and Pause taken together, were made in about five Minutes, or a little more.

"I COULD observe by the Mark upon the Stones, that the Surface of the Water in the Bason had rose before we came, at least three quarters of an Inch perpendicularly higher than when we saw it; and I thought that I could perceive some very little Abatement each Turn, both in the Height and in the Time of the rising of the Surface, and consequently in the Time of its sinking; but the Time of the Pause, or standing of the Surface at its usual Height, or equable running of the Stream, was lengthened, yet so, as to leave some Abatement in the Time of the Rising, Sinking, and Pause taken together; this is all which my short Time would allow me to observe. Many more things should have been taken notice of, as will appear from the Hypothesis proposed to explain these Phænomena.

"BUT before I enter upon explaining that Hypothesis, I must remark what Difference or Agreement is to be found between this Account of the Fountain, and another published in the *Philos. Trans. Numb.* 204. p. 909, 910. in two Letters from Dr. *Oliver* to *Walter Moyle* Esq; The Doctor places it a Mile and half from *Brixam*, I suppose he means *Brixham-Quay*, which is more than a Mile off from the Town. He gives the Dimensions of the Bason a little different from mine, making the Surface of it thirty Foot square; whereas I make it thirty-six Foot: He says, that it ebbs and flows very often every Hour, which is certainly false, as appears both

" by

" by common Report, and by my own Obſervation: When it once begins " indeed to flow and ebb, it continues to do ſo ſeveral times in an Hour; " but then there is after this again a certain Space of Time, perhaps two " Hours or more, when it runs with an equal Stream, without any the leaſt " Variation; and this is a particular Circumſtance not obſerved in any Spring " whatſoever that I have heard of. When the Doctor firſt ſaw it, *viz.* in " *July* 1693, he ſaid that he judg'd the Flux and Reflux, as he calls them, " to be performed in about two Minutes: if he means two Minutes each, it " agrees very well with my own Obſervations: but as he had neither Glaſs " nor Minute-Watch with him, this Obſervation cannot be depended on. " When he ſaw it again, *viz.* *Auguſt* the ſame Year, he judged it to flow " ſlower than before, which he explains by ſaying, that though it performed " its Flux and Reflux in a little more than a Minute (which by the way is " quicker than before) yet it wou'd ſtand at the low Water-mark two or " three Minutes, which I ſuppoſe he calls flowing ſlower than before, be- " cauſe the ſpace of time between the end of the Ebb and the beginning of " the ſucceeding Flux was longer. I had never read this Account till lately, " long ſince my own Obſervations were made; but, if we ſuppoſe the Doc- " tor to have made his Obſervations ſomewhat nearer the Time when the " Fountain was to ceaſe ebbing and flowing than I made mine, our Obſer- " vations will perhaps exactly agree, the Time of the Flux and Reflux be- " ing ſhorter, the Time of the Pauſe longer; but the whole Time of the " Flux, Reflux, and Pauſe taken together, being ſhorter by his Account than " by my own. He ſays, that he found it by his Watch to flow and ebb ſix- " teen times in an Hour; I do not ſuppoſe that he made a whole Hour's " Obſervation; which muſt have ſhewn him a Difference in the Times of the " Reciprocations that he did not perceive; but having obſerved, that one " Reciprocation, or a Flux, Reflux, and Pauſe, took up the ſpace of four " Minutes; he from thence computed, as I imagine, that would be ſixteen " in an Hour, preſuming that there was no Alteration in the Times. In this " ſenſe I would underſtand him, when he adds, that he was informed it " ſometimes flowed twenty times in an Hour. For, according to his Obſer- " vations, it flowed at the Rate of ſixteen times in an Hour; according to " my own Obſervations, at the Rate of twelve times in an Hour; perhaps " before my Obſervation at a leſs Rate, and after his at a greater. So that in " a whole Hour, according to the ſeveral Rates taken together, it may flow " and ebb about nine or ten times, according to another Account which I " have received; but of this I can aſſert nothing certain, or upon my own " Obſervations. The Doctor adds, that when the Water in the Baſon began " to riſe, he obſerved a Bubbling in the Bottom of the Baſon, which ceaſed " when the Water began to ſink. This I did not ſee, becauſe the Springs " were ſmall and low, by means of a dry Seaſon; but it was confirmed to " me by the Report of Eye-Witneſſes, as is before obſerved.

" Having thus compared the two Accounts given of this Fountain, I " come now to my Hypotheſis, for explaining the Phænomena obſerved " by me; and I imagine them to be occaſioned by two Streams or Springs,

" one

Annotat. Lect. VIII. "one of which passing through two Caverns, or natural Reservoirs, with Syphons, meets with the other Stream in a third Reservoir, without a Syphon, "where being joined, they come out of the Earth together. This complicated "Piece of Machinery will be best understood by beginning with an Explanation of the more simple Parts first; in doing of which, we shall have an "Opportunity of considering some other sorts of Fountains, which have already been observed, or may hereafter be found to be in Nature.

"The *Petitio Principii*, or Supposition of Reservoirs and Syphons in the "Bowels of the Earth, has been made by others; *Pére Regnault*, in his *Phil.* "*Conversations*, *Vol.* 2. *Conv.* 6. *P.* 125. *&c. Eng. Edit.* has mention'd it in "general; and Dr. *Desaguliers*, in *Phil. Transf. Numb.* 384. has attempted to "apply it to two Cases in particular; as *Dechales*, *Tract.* xvii. *de Fontibus Naturalibus*, *&c. Prop.* xv. had done in two other Cases before him. Nor is it "unnatural, or hard to be granted. Whosoever has seen the Peak of *Derbyshire*, the hilly Parts of *Wales*, or other Countries, must be satisfy'd that they "abound with Caverns of many sorts. Some of them are dry, others serve "only for Passages, or Channels to Streams which run thro' them; and a third "sort collect, and hold Water till they are full. They must likewise have observed, that there are sometimes narrow Passages running between the Rocks, "which compose the Sides, and going from one Cavern to another, such a "Passage, of whatsoever Shape or Dimensions, how crooked soever in its "Course, if it be but tight, and runs from the lower Part of the Cavern, first "upwards to a less Height than that of the Cavern, and then downwards "below the Mouth of the said Passage, will be a natural Syphon."

Plate 16. Fig. 7. A NATURAL Reservoir then, *Plate* 16. *Fig.* 7. A B C D, with such a natural Syphon, M N P, may be supposed. Let a Stream, which I shall call the Feeding-Stream, enter it, near the Top, at O. The said Cavern must contain all the Water which comes in at O, till it is filled to the Top of the Syphon at N. Then the Syphon beginning to play, and being supposed always to discharge more Water than comes in at the Feeding-Stream at O, will empty the Cavern, till the Water is sunk in it below the Mouth of the Syphon at M; when it must stop, till the Cavern is filled, and the Syphon runs again, as before. If the Water discharged by such a Syphon, M P, be brought out of the Earth by a Channel P Q, the Water will flow out of the Earth, and stop alternately, making an intermitting Fountain at Q.

BY this plain and easy Contrivance, several of the flowing and ebbing Springs observed by the Naturalists may probably be explained, and even a much greater Variety of them than is hitherto known. For if the feeding Stream at O should arise only from the Rains in Winter, or from the melting of Snow in Summer, the intermitting Fountain would become a temporary Spring, as Dr. *Plot* calls such Springs which are confined to a Season: or if the feeding Stream at O should be constant, but yet liable with other Springs to increase and decrease, arising from the Seasons, Weather, or other Causes, the Construction of the Syphons would make great Alteration; for when the Syphon is so made, that its Discharge (which is continually decreasing, as the Surface of the Water subsides in the Cavern) shall at any time be

be equal to the Feeding-Stream entering at O, in ſuch a caſe, the Syphon muſt continually run, and yet not empty the Cavern, till the Feeding-Stream at O is ſufficiently diminiſhed. But when the Diameter of the Syphon at N, according to the Height of the Cavern, is ſo great, and the Feeding-Stream at O ſo ſmall, that the Syphon can carry off (in the manner of a Waſte-Pipe) all the Water which comes in, and yet not run with a full Stream, the Syphon muſt then continue to run without emptying the Cavern till the Feeding-Stream at O is ſufficiently enlarged. So that by theſe different Conſtructions of the Syphon there may be ſome Fountains which ſhall flow conſtantly in the Winter, or a wet Seaſon, and intermit in the Summer, or a dry Seaſon; and on the contrary, others which ſhall flow continually in the Summer, or a dry Seaſon, and intermit in the Winter, or a wet Seaſon. There is a third Variety, which may ariſe from the Make of the Syphons, and will occaſion ſuch Irregularities as admit of no certain Explanation. This happens when the Diſcharge of the Syphon at the very laſt is juſt equal to the Feeding-Stream, and the Cavity of the Syphon at N is large; for in this caſe the Air-bubbles, made by the Fall of the Feeding-Stream from O, to the Bottom of the Cavern, will ſometimes accidentally get into the Mouth of the Syphon at M, and lodging at N, will ſo choak it, as to render its running and ſtopping, as well as the Quantity of its Diſcharge, entirely uncertain; ſo that theſe ſort of Fountains will admit of no farther Conſideration.

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Plate 16. Fig. 7.

But before I leave the Conſideration of Fountains explicable by one Reſervoir and Syphon, it may not be amiſs to obſerve, that thoſe which intermit regularly will have their Flux always longer, and their Pauſe, or Intermiſſion, ſhorter in Winter, and in wet Weather, than in Summer, or in a dry Seaſon; which is a Conſequence of this Hypotheſis, by which it may be examined, whether it be applicable to any particular intermitting Fountain, or not.

If the ſingle Reſervoir and Syphon has another Outlet at R, *Fig.* 8. ſituated between the Bottom C D of the Cavern, and the Top of the Syphon N, we ſhall have another kind of Fountains. For if the Feeding-Stream at O is capable of being diſcharged by the Out-let at R, a Fountain derived from R will continually run, whilſt the Feeding-Stream can be diſcharged that way, and will encreaſe and decreaſe with any little Alteration happening to the Feeding-Stream at O, provided that the ſaid Stream does not grow too large for the Out-let at R. But in that caſe the Cavern muſt be fill'd up to N, and the Syphon may begin to play; which, together with the Out-let at R, may diſcharge ſo much as to make the Surface of the Water in the Cavern ſink below R, and conſequently the Fountain proceeding from R muſt ſtop. If the Diſcharge of the Syphon is ſo great as to empty that Cavern, then the Fountain derived from R will, after ſome time, begin to run again, and encreaſe till the Water riſes in the Cavern to N; after which it will decreaſe, and at length ſtop. But if the Diſcharge of the Syphon only keeps the Surface of the Water below R, without emptying the Cavern, then the Fountain derived from R ſhall be dried up, ſo long as the Stream at O continues encreaſed, and ſhall run again when the ſaid Feeding-Stream is leſſened. Thus we may have a Spring which ſhall run all Summer, and be dry all Winter: ſuch a Spring

Plate 16. Fig. 8.

Annotat. Lect. VIII. Plate 16. Fig. 6.

will encreaſe juſt before it begins to fail, *i. e.* whilſt the Water in the Cavern is riſing to N, will be dried up ſooner in a wet Summer, and break out later in a wet Winter, contrary to the Nature of other Springs. Which Particulars are worthy of Obſervation in ſuch ſort of Springs, (of which it is ſaid we have ſome in *England*) and will ſerve to diſcover, whether they are occaſioned by this kind of Machinery, or not.

If the Syphon, *Fig.* 9. M N P of the Reſervoir A B C D, having no Out-let at R, ſhould diſcharge itſelf into a ſecond Reſervoir, E F G H, of a ſmaller Capacity, but furniſhed with a Syphon S T V, which diſcharges the Water more plentifully than it comes in; a Fountain derived from this ſecond Syphon S T V, would flow and intermit, whilſt the firſt Syphon M N P continued running, *i. e.* 'till the great Reſervoir A B C D ſhould be emptied. After which, it would entirely ſtop till the ſaid Reſervoir A B C D was filled again by the Feeding-Stream at O, and then it would flow and intermit, as before.

Such a ſort of compound Fountain would be liable to all the Variations of the former Fountains derived from a ſingle Reſervoir: if we take the Fits of flowing and intermitting of this for the Flux of the former; and a long Stop in this, whilſt the great Reſervoir is filling, for the Pauſe or Intermiſſion of the former. Beſides which, we muſt remark, that as the Flux in the former Fountains may be changed, and be made longer or ſhorter; ſo in this, the number of Intermiſſions during one Fit of flowing and intermitting, may not always be the ſame, becauſe of the different Capacities of the two Reſervoirs, and a Difference, or Change, occaſioned in the Feeding-Stream at O. For if, whilſt the great Reſervoir A B C D is emptying, the little Reſervoir E F G H ſhould empty itſelf nine times, for inſtance, and be full again, the Fountain derived from its Syphon S T V muſt have nine Intermiſſions in one Fit, and ten in another, alternately, whilſt the Feeding-Stream at O remains the ſame. But the Feeding-Stream at O, being leſſened or enlarged, without making the Syphon M N R run continually, the number of Intermiſſions in each Fit will be diminiſhed or augmented accordingly. But 'tis peculiar to this laſt ſort of Fountains, that in each Fit of flowing and intermitting, the firſt Flux will be larger and longer than the ſecond, and the ſecond than the third; but the firſt Intermiſſion will be ſhorter than the ſecond, and the ſecond than the third: becauſe the Syphon M N P running faſter at the firſt than at the laſt, the Reſervoir E F G H muſt be a ſhorter time in being filled, and a longer time in being emptied the firſt time than the ſecond; the ſecond than the third, and ſo on. As to the whole Time of the firſt Flux and Intermiſſion, in compariſon of the whole Time of the ſecond Flux and Intermiſſion, it is a Particular, requiring ſo many things to be taken into Conſideration, for determining it in each Caſe, that I ſhall wave it here, and content myſelf with ſhewing that it may be longer, by an Experiment that will preſently be made. Another Variety in this ſort of Fountains might be made by a ſecond Feeding-Stream Z, coming into the ſecond Reſervoir E F G H; but the bare mentioning of that will at preſent be ſufficient.

If in the Contrivance of a ſingle Reſervoir and Syphon, the Stream derived from the Syphon ſhould fall into another Reſervoir, *Fig.* 10. I K K L, having no Syphon, but only a common Out-let X, and ſhould in this Reſervoir meet

meet and join with another Stream conſtantly running, a Fountain derived from the ſaid Out-let X would be a reciprocating Spring; by which Name I call thoſe Springs which flow conſtantly, but with a Stream ſubject to encreaſe and decreaſe, to diſtinguiſh them from intermitting Springs, which flow and ſtop alternately. And if the Out-let X be too ſmall to carry off all the Water brought into the Reſervoir I K K L by the Syphon, over and above what is brought in by the conſtantly running Stream W, then the Surface of the Water in the ſaid Reſervoir I K K L muſt continually riſe, till the Velocity of the Stream going out at X, is ſufficiently encreaſed, to carry off the Water coming in. Upon which, the Diſcharge of the Syphon being continually leſſened, the ſaid Surface will again ſubſide, and the Velocity of the Stream at X will diminiſh; ſo that both the Encreaſe and Decreaſe in this reciprocating Fountain will be gradual. Beſides, if the Reſervoir I K K L, or the Channel derived from it, ſhould have any Leaks, Crevices, or other Out-lets, the Water will iſſue through them upon the riſing of the Surface in the ſaid Reſervoir, and occaſion Springs, which will ceaſe again when the Surface ſubſides. Let us now ſuppoſe ſuch a Reſervoir, *Fig.* 11. I K K L, with a conſtantly running Stream W, and an Out-let X to receive the Water of a Syphon S T V, coming through two Reſervoirs A B C D, and E F G H, as before deſcribed. A Fountain derived from X, in this Caſe, would be an intermitting, reciprocating Spring, whoſe Stream would reciprocate, but whoſe Reciprocations would ſometimes ſtop, and have Fits of Intermiſſion.

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Plate 16. Fig. 10.

Plate 16. Fig. 11.

Such, in all probability, is the Fountain called *Laywell*, before deſcribed, whoſe Phænomena gave occaſion to theſe Thoughts, and ſeem capable of being accounted for by ſuch a Contrivance. And, for the better Diſcovery of the Nature of this Fountain, whether it is owing to ſuch a Piece of natural Machinery, or otherwiſe, it would be proper to obſerve the Length of Time of each Encreaſe, Decreaſe, and Pauſe in every Reciprocation, together with the number of Reciprocations in every reciprocating Fit, and likewiſe the Length of the Intermiſſions of the ſaid Fits. Theſe Obſervations ſhould be continued for ſome time, both in a ſettled Seaſon, when the Feeding-Stream at O cannot change, and in variety of Seaſons, when the ſaid Stream may be altered.

Having now brought theſe Thoughts to the End propoſed, *viz.* an Explanation of ſuch a Fountain as *Laywell*, I ſhall carry them no farther; but conclude, by preſenting to the View of the Society an artificial Fountain of this kind, *Fig.* 11. which being very eaſily made, may be buried in the Bottom, or Slope of a Terraſs, where a conſtant Stream of Water can be brought, and will furniſh us with a new ſort of Water-Works in Gardens. The two Reſervoirs A B C D, E F G H, with their Syphons M N P, S T V, and the third Reſervoir I K K L, with its Out-let X, are included in a Box Y Y Y Y. Into this Box at λ enters a Funnel Γ λ Γ, divided within the Box into two Pipes, *viz.* λ O, which ſerves for a Feeding-Stream to the great Reſervoir, and λ W, which ſerves for a conſtant Stream to the third Reſervoir. A Stream of Water being let into the Funnel Γ λ Γ, will diſcharge itſelf like ſuch an intermitting Fountain at X, where there is a Baſon Y Z Z Z without

Annotat. Lect. VIII. the Box to receive it; with an Out-let α, and a Diagonal Gage Z Y, to mark the Rise and Fall of the Water in the Bason.

5. [18.—*The best way of making the Valves*, &c.—] Monsieur *Belidor*, in the second Volume of his *Architecture Hydraulique*, mentions a new kind of Valves of his Invention, which he prefers to any that he ever saw; and in the Account of the great Improvements that he made to the *Machine* of the *Samaritaine* upon the *Pont neuf* at *Paris*, he mentions these new Valves, and his new Pistons, as the principal Parts alter'd much for the better. All the Objection I have against them, is, that I think it very difficult for the Workmen to make them, otherwise I think them extremely well contriv'd; and since he found Workmen that made those which he used at the Renewal of the *Machine* of the *Samaritaine*: I thought it would be acceptable to the Reader to give Draughts and Descriptions of them here.

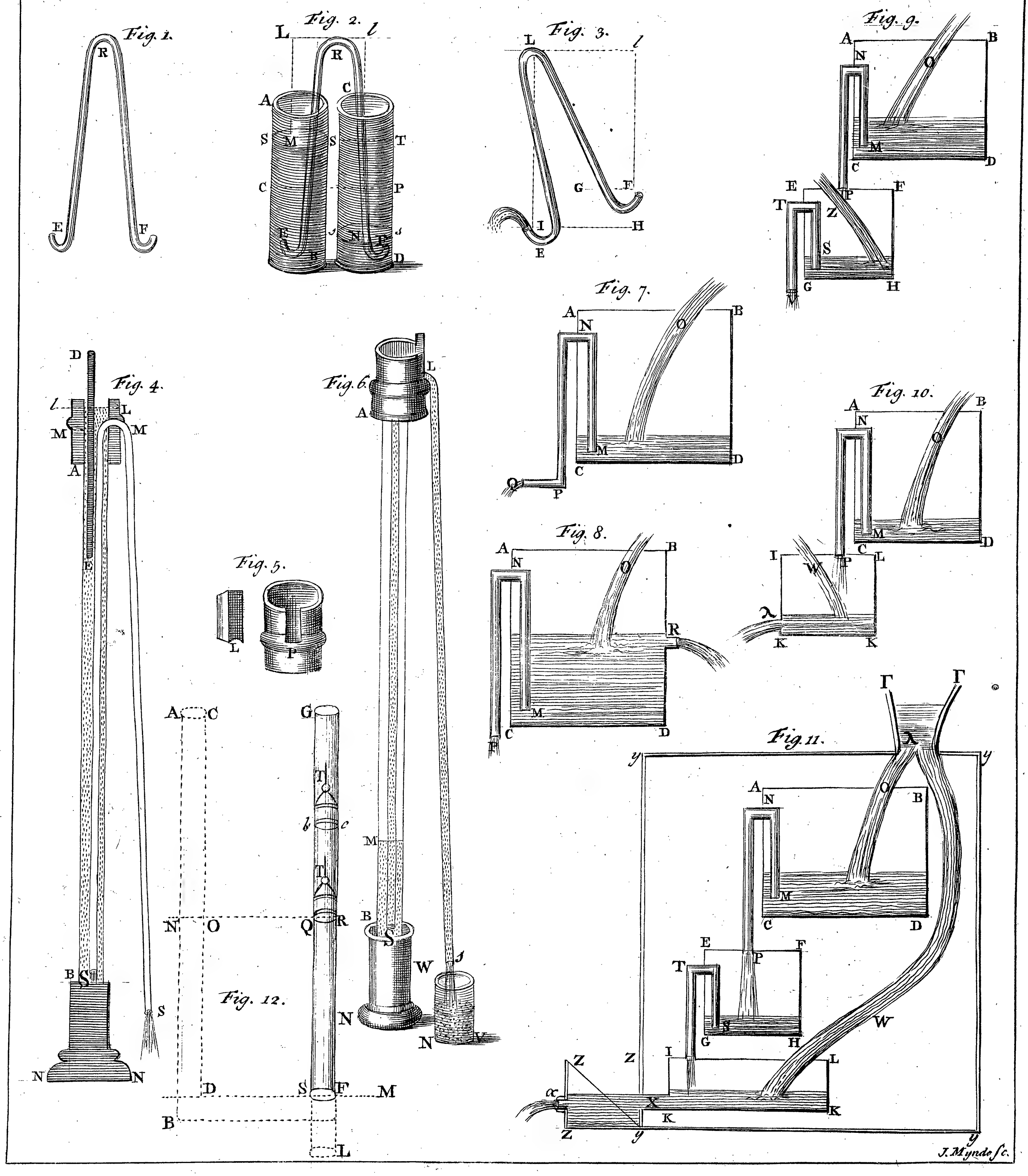
Plate 17. *Fig.* 1, 2, 3, 4, 5, 6, 7.

Plate 17. Fig. 1, 2, 3, 4, 5, 6, 7. The first Figure represents a round Plate of Brass, one half of which is chamfer'd upwards, and the other half downwards. The Half C A D, which is greater by $\frac{1}{12}$ than the other Half B, is taper'd on the under Side from L to A, as you may see plainer in *Fig.* 7. where the same Letters are used. The other Half B is taper'd on the upper Side, as may also be seen in *Fig.* 7. at B M. On the upper Side of this Plate, nearer B than the Center G, is screw'd on with three Screws, an Axis E H F, with Gudgeons or Pivots E F, on which the Plate turns in its Motion. The second Figure shews how this Axis is fasten'd to the Plate.

The third Figure represents the Box, or Bed of the Valve, chamfer'd downward on all the semi-circular Side L, to receive the Part A L of *Fig.* 1. falling upon it: and the other Part B, quite to A A, the Place where the Pivots of the Axis are to rest, is chamfer'd upwards from below, to receive the Part B of the Valve of *Fig.* 1. coming up against it. From these chamfer'd Edges on the Inside, this Bed of the Valve spreads into a flat Ring to be pinch'd between the Flaunches of the Pipes, (whether of Iron or Brass) which are screw'd together with Leathers between, to make all tight. The fourth Figure represents the Section of this Bed, where O P represents its upper Part chamfer'd downwards to receive G L A, the greater Half of the Valve of *Fig.* 1. falling upon it: and Q R, chamfer'd upwards, receives the smallest Half B of the Valve of *Fig.* 1. rising against it, as it shuts. The Valve thus shut in its Bed, or Bore, is represented in *Plan* by *Fig.* 5. where you may see that the Pivots, or Ends of the Axis, are kept in their Places by semi-circular Bridles, that go over them at C and D. The Section of the same Valve shut may be seen at *Fig.* 6. where M B H G represents the lower and lesser Half of the Valve shut, and applied upwards to the under Part of the Bed at Q R; and L A G H represents the bigger Half of the Valve shut, and applied downwards to the Bed at O P. K shews one of the Bridles pinn'd, which holds down the Pivots, or Ends of the Axis.

The

Plate XVI.



J. Mynde sc.

The seventh Figure shews the Valve open, and the Manner of its Play.

By observing that all the Passage is open between Q K and B I L, and between P O and M H A, it is plain that here is the greatest Water-Way possible. Now when the Valve shuts, the End B M moves in the Direction of the prick'd curved Line M Q, and the End L A in the Direction of the prick'd Line L O. When the Water is coming downwards, it must push hard on the greater Half of the Valve mark'd G A L, in *Fig.* 1, 5, 6, and 7. and thereby make the Part B H, shewn by the same Figures, to rise; by which means the Valve will be close shut. But when the Water comes upwards, as it presses with more Force upon the Surface G A, because it is larger, the Part H B will come down, and the Valve will immediately open. Plate 17. Fig. 7.

At first, one would imagine, by observing the Valves quite upright on Edge, that this Valve would not shut readily, and so lose Water; but its ingenious Inventor has remedied that Inconvenience, in the following manner. As the Axis (see Part of it by itself in *Fig.* 7.) is higher than the Plan of the whole Valve H G having its Center at I, let the Lines G H, H I, and I K be drawn, and you will have the bended Leaver G H I K, whereby the Part A G of the Valve (even tho' it were no greater and heavier, and had not a greater Pressure upon it) acting by the Arm G H, would overpoise the other Part of the Valve H B M, which only acts by the Arm I K: so that the natural Tendency of the Valve is to be shut, but never to open but when the Water acts upwards against it. This may also be confirmed by observing, that if a Line be drawn from L to M, the Center of Gravity will be in that Line between G and H; and it is evident from the Inspection of the Figure, that that Center of Gravity must always descend, till it comes to rest under the Center of Motion I.

N.B. When Workmen can't easily be found to make this Valve right, I would prefer the Butterfly-Wing Valve described in the 16th *Plate*, *Fig.* 14. both for Pistons and Sucking or Forcing Pipes. Plate 14. Fig. 16.

Here follow Monsf. *Belidor*'s Pistons or Buckets, which are either lifting or inverted Pistons, as in the 8, 9, 10, and 11th Figures; or Sucking Pistons, as in the 12, 13, and 14th Figures. Plate 16. Fig. 8, 9, 10, 11, 12, 13, 14.

The lifting Piston consists of a short hollow Cylinder C D I K, which has at Bottom two Ears, Handles, or Side-Pieces, cut from the Cylinder, as E I, F K, (see *Fig.* 8, 9, 10, 11.) with an Hole thro' each, which is to receive a strong Pin M L (*Fig.* 9.) to join it to its lifting Rod P N O. This Cylinder has a broad Shoulder E F, standing out to stop several Rings of Leather which are slipped on upon the Cylinder, as you may see at G H, in *Fig.* 9, 10, 11. There is at the upper End a Male Screw C D, to receive the Female Screw A B. Upon the Face or Flat of this Screw is fastned with small Screws and a Leather between, the Valve above-mentioned, which appears shut in *Fig.* 8. the Section of the Piston, and in two other Views of it in *Fig.* 9, and 11. and open in *Fig.* 12.

In the sucking Pistons, (see *Fig.* 12, and 13.) the Valves are not screw'd to the Pieces that hold and squeeze the Leathers here mark'd F G (by A B in the

Annotat. Lect. VIII. the former Pistons) but are here fasten'd between the Handles C, D, screw'd on with small Screws upon a Return of the Cylinder.

Q (*Fig.* 12.) shews the Valve upright upon its Bed, H and L the Hollow of the Cylinder, and I K the Leathers: The Handle here is at top, with its Rod and Center-Pin; but is very apparent and easy to be understood from what has been said before.

FIGURE 13. represents the Piston with only one of its Handles at C; the other being taken off, the better to shew the Valve upright and in Front at Q. A B is the Return of the Cylinder, on which the Bed of the Valve is screw'd, and H L the Place of the Leathern Rings.

FIG. 14. shews the Piston look'd upon downwards from the Center-Pin that goes through the Handles. O P, O P, are the Handles traversed by the Center-Pin, but the Rod is off. M M, N N are the Places where the Bed of the Rod is screw'd, and Q is the Valve shut. You have here two Scales, in Diameters of the Barrel of the Pumps in which these Valves and Pistons are used,——the one larger for the Valves, and the other less for the Pistons.

N.B. These Pistons require to be very exact, turn'd in a Lathe when fitted, and the Barrels in which they work to be nicely bored, otherwise they will not be tight. But if you add to them a thin Leather, folding upwards at A B, (*Fig.* 12.) and another folding downward at F G, they'll do any where, and be tight notwithstanding some Irregularities. Such a Leather may be seen in our Force-Pump, *Plate* 15.

6. [22.——*If it be desired to know to what Height Water will rise in any Pump at every Stroke of the Piston, it can be found by Algebra; provided the Play or Stroke of the Piston, and its Distance from the Surface of the Water, be known.*]

LET us first take the Sucking-Pump, in which it is necessary to remember what has been said before, that when the Bucket has been raised, and consequently the Water has got up to any Height in the Pipe, the Weight of the outward Air is held *in Æquilibrio* by a mix'd Column in the Pipe, made of Air still a little dilated, and of a certain Quantity of Water. Whence it follows, that the dilated Air in the Pipe has a Part of the Weight of the Atmosphere, and the Water has the remaining Part; and consequently that those two Weights being expressed by way of Fractions of the Weight of the Atmosphere, and added together, are equal to Unity, *or the Number One.*

LET us now take twelve Foot for the Distance of the Bucket from the Surface of the outward Water, when it is at the lowest, and 4 Foot for the Length of the Stroke; so that it moves from 12 to 16; and let us call x the Height to which it has raised the Water in the Pipe by the first Stroke: Then it is evident that the Air which, before the Rising of the Piston, was contained in $BD = 12$, is now contained in $AC = 16 - x$, and consequently that its Weight or Pressure is $\frac{12}{16} - x$ of what it was before, that is, of the whole Atmosphere. The Weight of the Water got to x, is $\frac{x}{32}$ of the Atmosphere; supposing a Column of Water 32 Foot high, equal to the Weight of the whole Air: For if

if x were one Foot, it is evident it would be $\frac{1}{32}$ of such a Column, (and it is the same of any Height) these two Fractions being together equal to the whole Atmosphere, gives the following Equation: Annotat. Lect. VIII.

$\frac{12}{16} - x + \frac{x}{32} = 1$, then
$384 + 16x - x = 512 - 32x$ freeing it from the Fraction $-x^2 + 48x = 128$ by Transposition.
Changing the Signs. $x^2 - 48x = -128$.
$x^2 - 48 + 576 = 448$ compleating the Square. Since
$576 - 128 = 448$
$x - 24 = \pm 21{,}166$ extracting the Roots
$x = 2{,}834$ by Substraction.

To calculate the Rise of Water at the second Stroke, call it x as before, (it is the Height to which the Water has risen at the second Stroke above the known Height to which it rose at the first,) the Equation becomes $\frac{12 - 2{,}834 = 9{,}166}{16 - 2{,}834 - x = 13{,}166 - x} + \frac{2{,}834 + x}{32} = 1$, which after the due Reduction makes $x = 2{,}264$ *, or making $x =$ the Height to which Water has risen by the two first Strokes together, the Equation becomes $\frac{9{,}166}{16 - x} + \frac{x}{32} = 1$; which being reduced, gives $x = 5{,}098$, from which Number if 2,834, the Rise caused by the first Stroke, be substracted, the Remainder is 2,264, for the Rise caused by the second Stroke as before. The latter Equation has this Advantage above the former, that it is more easily reduced. It is evident that it will serve to find the Rise at every Stroke; only changing the Numerator of the first Fraction, which always is 12 less the Height to which Water was risen before.

After this Method it has been calculated that the Water rises

		Addition.
at the first Stroke,	2,834 . .	
at the 2d, ———	2,264 . .	5,098
3d, ———	2,025 . .	7,123
4th, ———	2,043 . .	9,166
5th, ———	2,413 . .	11,579
6th, ———	3,620 . .	15,199

After almost the same way we can calculate what is the greatest Height to which Water can rise in a Pump, which is not able to bring it to the Bucket: As for example, let us suppose the Distance of the Bucket from the Surface of the outward Water to be 25 Foot, and its Play or Stroke to be three Foot, so that it moves from 25 to 28, and let us call x the greatest Height to which it can raise Water. Then it is evident that the Air which was contained in $25 - x$, when the Bucket was down, is contained in 28 less x, when it is up, and consequently that its Pressure is $\frac{25 - x}{28 - x}$ of what it was before, *viz.* of the

* By a second Trial that Equation x is found $= 2{,}226$, and in the latter $x = 5{,}10$.

Annotat. Lect. VIII. the whole Atmosphere. The Weight of the Water which is got up to x, being $\frac{x}{32}$ of the same Atmosphere, and those two Fractions being together equal to an Integer or Atmosphere, we have the following Equation:

$\frac{25^2 - x}{28 - x} + \frac{x}{32} = 1$, then

$800 - 32x + 28x - x^2 = 896 - 32x$ freeing it from the Fractions.

$x^2 - 28x = -96$ by Transposition, and changing the Signs.

$x^2 - 28 + 196 = 100$ compleating the Square.

$x - 14 \pm 10$ extracting the Root.

$x = 24$ by Addition, or 4 by Substraction.

This shews that there are two Heights, 4 and 24 Foot, to which if the Water rises in the Pipe, its Weight, together with the Pressure of the dilated Air in the Pipe, will hold the outward Air *in Æquilibrio.*

If the Water was to be poured to any Height between them two, it would be too heavy; and in all Heights above 24, or below 4, it would be too light. 4 Foot is therefore the Height to which such a Pump can raise the Water; for tho' 24 answers as well to the Weight required, as the Water would become too heavy at all Heights between 4 and 24, it cannot rise above 4.

The same Rule will serve for any other Cases.

The Rise of Water in Forcing-Pumps, may be calculated after the same manner, by taking the oblique Pipes, as if they were perpendicular ones; because the Direction of them changes nothing as to the Dilatation of the Air.

There is no occasion for it in the Lifting-Pump, which works merely by the Valves, without any Dilatation of the Air, and where the Rise of the Water at every Stroke, is equal to the Stroke itself.

LECTURE

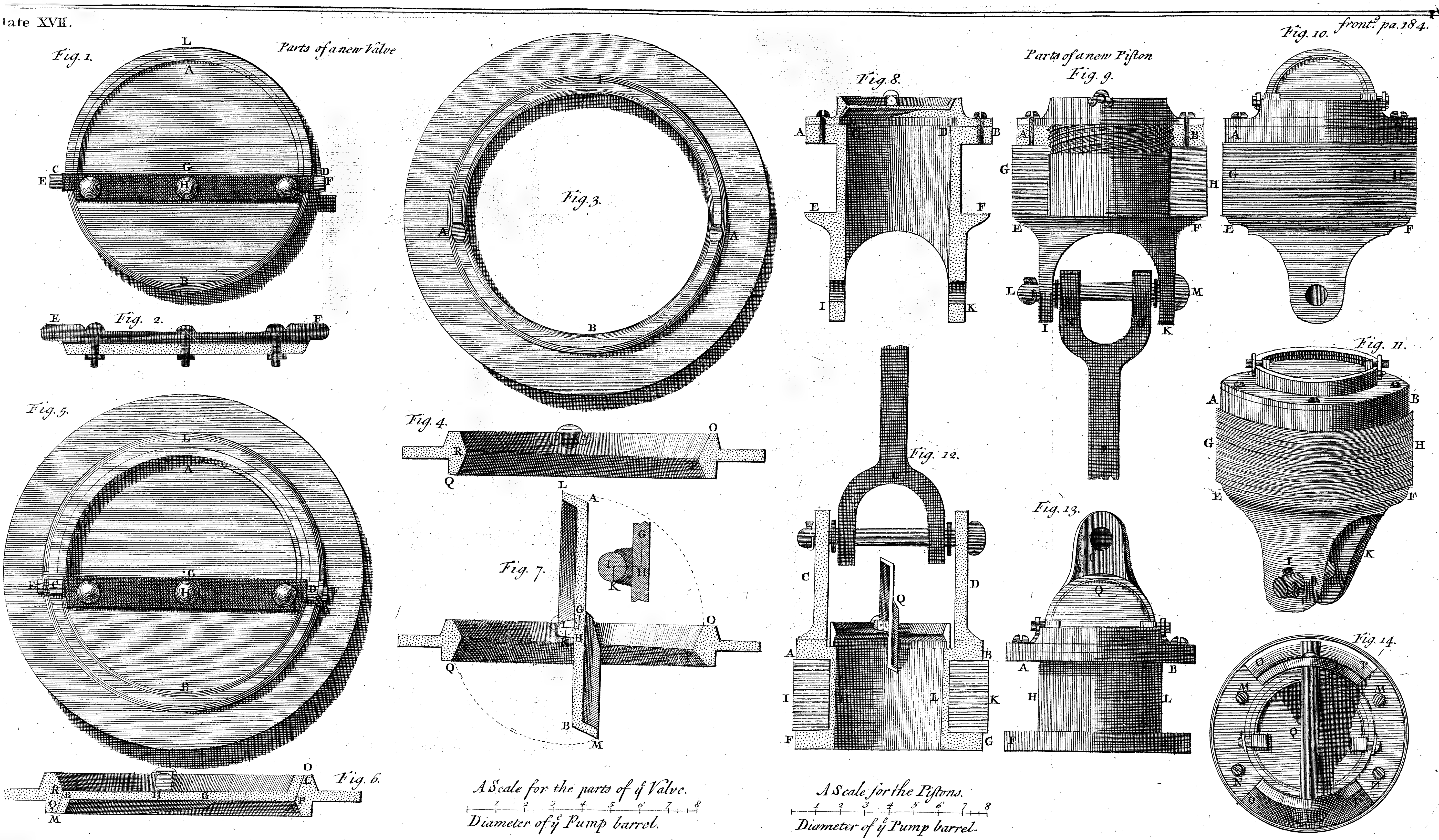


Plate XVII.
front. pa. 184.
Parts of a new Valve
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Parts of a new Piston
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
A Scale for the parts of ye Valve.
Diameter of ye Pump barrel.
A Scale for the Pistons.
Diameter of ye Pump barrel.
J. Mynde Sculp.

LECTURE IX.

HYDROSTATICKS.

Lect. IX. Plate 18. Fig. 1.

1. A Body ſpecifically heavier than a Fluid, loſes as much of its Weight in that Fluid, as a Bulk of the Fluid equal to the Body weighs; and the Fluid gains as much Weight as the Body weighed in it loſes.

EXPERIMENT 1. *Plate* 18. *Fig.* 1.

C is a Cylinder of Lead weighing five Pounds and an half, made of ſuch a Size as exactly to fill the Bucket, or hollow Braſs Cylinder A, which Cylinder is a Counterpoiſe to the Weights P *p* in the Scale B, at the oppoſite End of the Balance E F, on which it hangs. The Lead C is kept *in Æquilibrio* by the Weights of P of 5 Pounds, and *p* of half a Pound, in the Scale B. Now let the Jar of Water D, filled up to S S, be kept *in Æquilibrio* in another Balance by W in the oppoſite Scale G. Now let C, as it hangs, be brought over the Jar D, and let down into it, and the Lead, as it ſinks under the Water, will loſe of its Weight; ſo that you muſt take out the little Weight *p* to reſtore the Lead (now immerged under the Water) to its Æquilibrium: But as by the Immerſion of the Lead into D, as at C, D with its Water will become heavier, you muſt put the Weight *p*, taken from the Scale B, into the Scale G at W; by which means you will reſtore the Æquilibrium to D, balancing what the Water had gained. This proves that what the Lead loſes the Water gains. Now to prove that the Lead loſes juſt as much as an equal Bulk of Water weighs; let the Jar D be fixed, and the Weight *p* left in the Scale B; then the Lead C will not be wholly immerſed in Water, till you fill the Cylinder or Bucket A with Water, whereby the Lead will ſink to C, ſo as to be covered with Water, which it will raiſe to *s s*, and its Æquilibrium with the Scale B will be reſtored. Thus the Quantity of Water that filled A, appeared equal in Weight to what the Lead loſt; becauſe being added to it, it reſtored it to its Æquilibrium (when the Lead was immerſed:) And we have proved it equal in Bulk to the Lead before, becauſe the Lead juſt fills the hollow Cylinder A when put into it. Now again, let us take the Lead out of D, which being let

Lect. IX. looſe, will on the Beam V be counterpois'd by the Weight W in the Scale G; then pouring into D the Bucket full of Water A, the Surface S S will riſe up to *s s*, and D become heavier, till it be counterpois'd by the Weight *p*, replaced near W in the Scale G; the Water being rais'd to the ſame Height by that Addition, as when the Lead was immers'd in it, whoſe Immerſion did the ſame as encreaſing the Bulk of the Water in Proportion to the Bulk of the Lead.

Corollary.

Hence it follows, that what the Water gain'd, was not in Proportion to the Weight, but the Bulk of the Lead: and that the Water would have gain'd as much by the Immerſion of any other Body of the ſame Bulk as the Lead; and that any other Body of the ſame Bulk as the Lead, would have loſt as much Weight as the Lead loſt; not ſuch a Proportion of its own Weight as the Lead loſt.

Corollary 2.

Hence follows alſo, that if a Body ſpecifically lighter than Water, as big as the Lead, be held in it by Force, it will add to the Weight of the Water as much as the Lead did in the laſt Experiment. It may be thus proved;

Experiment 2. *Plate* 18. *Fig.* 2.

Plate 18. Fig. 2. Let there be a Cylinder C of light Wood, hanging down from a fix'd Body as G H; this Cylinder muſt be of the ſame Diameter with the Lead, but may be much longer, and muſt have a Mark or circular Line at *c*, to ſhew how much of it is equal in Bulk to the Lead. Then let the Balance mark'd V in *Fig.* 1. (with the Bucket hanging from E, and the Scale G at the other end, having in it the two Weights W and *p*) be brought to G H and C: the Jar or Glaſs Bucket D, which is now over-balanc'd by the oppoſite Weights, will take in the wooden Body C into its Water up to *c*, and then be *in æquilibrio* with the Weights in the oppoſite Scale; which ſhews that the Water gains the ſame by the Immerſion of any Body equal in bulk to the Lead, whatever be that Body's ſpecifick Gravity.

Scholium.

Since the Water that fill'd the little Bucket A, *Fig.* 1. was equal in Bulk to the Lead, and in Weight to what the Lead loſt, and the Lead loſt the Weight of P which was half a Pound, the whole Lead weighing

weighing 5 Pounds and ½, it appears that Lead is eleven times specifically heavier than Water. Now if you subtract the Weight of an equal Bulk of Water from the Lead, or 1 from 11, (that is, 1 half Pound from 11 half Pounds) there will remain 10, the Weight with which the Lead descends in Water, and this is callled its *respective Gravity.* Thus in any Body that sinks in Water, it is the Weight which a Body continues to have in Water, when you have deducted from it the Weight of an equal Bulk of Water, and that it descends with. *N. B. The same may be said of any Body that sinks in any other Fluid whatever, viz.* that it descends with its respective Gravity. Lect. IX. Plate 18. Fig. 3.

EXPERIMENT 3. *Plate* 18. *Fig.* 3.

2. IF a Solid S, specifically heavier than several Fluids WW, be weigh'd first in Air, and then successively in these Fluids, it will shew their different specifick Gravities, which will be in Proportion to what it loses of its Weight in those several Fluids, that being the heaviest Fluid in which it loses most of its Weight.

3. A FLUID WW may serve to find out the specifick Gravity of any solid Bodies specifically heavier than it self: That solid having the greatest specifick Gravity that loses least of its Weight, when weigh'd in it.

4. A FLUID specifically heavier than several Solids may serve to find their specifick Gravities, if they be made to swim in it; for their specifick Gravities in respect to each other, will be as their Parts immers'd. The Manner of doing this has been already shewn *. * Lect. 7. N° 13.

5. A SOLID specifically lighter than several Fluids, will serve to find out their different specifick Gravities; for it will sink deepest in the Fluid whose specifick Gravity is the least. An Instrument made for this purpose is called an *Hydrometer* or *Water-poise*, and by some an *Areometer* ||. It consists of a small even Glass Tube A B, *Fig.* 4. hermetically seal'd, having on it a Scale mark'd of equal Divisions, with an hollow Ball of about an Inch Diameter at bottom, *Fig.* 4. and a smaller Ball C under it, communicating with the first. The little Ball has Mercury or small Shot put into it (before the Tube be seal'd) to make it sink in Water below the Ball; for Example to E, and stand upright in the Liquor in which it swims, the Divisions upon the Stem shewing how far it sinks. This, if in common Water it sinks to D, in salt Water it will sink only to E; in Port Wine it will sink to F; and in Brandy under Proof it will Plate 18. Fig. 4.

|| See that Word in *Harris*'s *Lexicon Technicum.*

Lect. IX. perhaps ſink to B. This Inſtrument of the common ſort is of no farther uſe, than to ſhew that one Liquid is ſpecifically heavier than another; but the true ſpecifick Weight of any one Liquid is not ſhewn without Difficulty, by making a Calculation for that particular Hydrometer; which muſt have its Tube truly cylindrick, and not tapering as they commonly are. But the worſt is, that theſe Inſtruments will not ſerve for Fluids whoſe Denſities are conſiderably different; for if they ſerve for Waters and Wines, they will ſink to the Bottom in ſpirituous Liquors; and if they be fitted for Spirits, the whole Stem will emerge below A in Waters and Wines. But if you uſe this only for different Waters, or Fluids that differ very little in ſpecifick Gravity, they may be made very uſeful. See the Notes, in which a very nice one is deſcrib'd, with Improvements upon the Inſtrument *.

Plate 18. Fig. 4.

* Ann. 1.

† Lect. 7 N° 14.

6. We have already ſhewn † in our 7th Lecture, that a Body ſpecifically lighter than a Fluid, if it be placed under the Surface of the Fluid, will emerge and come to the Top of the Fluid; but we have not ſhewn with what Force it wou'd riſe. The Force with which the light Body emerges, is the reſpective Gravity of the Fluid compar'd with the Body. For if Water, for Example, be 4 Times ſpecifically heavier than the Body, it will have its reſpective Gravity 3, whereby the Body will riſe with the Force 3; that is, an equal Bulk of Water ſtriving to deſcend into the Body's Place with the abſolute Force 4, while the Body gravitates downwards only with the Force 1, the Water diſplaces the Body, and makes it riſe with the Force 3.

Experiment 4. *Plate* 18. *Fig.* 5.

Plate 18. Fig. 5.

D is an hollow Cube of Tin (or white Iron) of two Inches the ſide, weighing an Ounce, being 4 Times ſpecifically lighter than Water, of which a Cube of the ſame Bulk weighs 4 Ounces. A B is an inverted Balance, moving round the Center C, fix'd to a Weight to keep it from being rais'd out of its Place. E F is a great Jar of Water, fill'd up with Water to the Line S S, on the Surface of which the Cube ſwims, ſinking only one Quarter of its Depth; but its under Part is faſten'd by a String to the End B of the Balance A B, in ſuch manner that if the other End be pull'd up to bring it to an horizontal Situation, the Cube will be brought quite under Water, from *d* to D. In order to do this, let the ſaid Plate E, making æquilibrium with the Weight of the Scale G of the Balance M N be ſo placed, that a String from the under Part of the Plate E is faſten'd to the End A of the Balance at *a*, while the Balance is in the oblique Poſition *ab*. Then putting 3 Ounces in the

the Scale G, the Cube will be drawn all under Water as the Balance is brought down to the Position A B. Which proves the Assertion above. N. B. *This may improperly be call'd weighing the* Levity, *or* Levitation *of a Body. I say improperly, because the Body does not rise as it is* light; *but as it is* less *heavy than the Water that displaces it.* Lect. IX.

7. When the Body D is loos'd from the Balance A B, it will rise up to the Surface of the Water, one fourth Part remaining under Water, and the other three fourth Parts standing up above the Surface; in which case, (as in all floating Bodies) a Bulk of Water equal to the immers'd Part of the Body, weighs as much as the whole Body: for as the imaginary Surface under the Cube must be press'd equally in all its Parts, it is the same whether in the Place where the Cube is, it sustains the Cube, or a Piece of Water equal in Bulk to the immers'd Part of the Cube, which will flow into it upon the Removal of the Cube *. But this may be further illustrated by an Experiment. Plate 18. Fig. 5, and 6.

* L. 7. N. 8, and 14.

Experiment 5. *Plate* 18. *Fig.* 6.

Let A B, a small Jar full of Water, stand in an empty cylindrick Dish C E, then laying the above-mention'd Cube D on the Surface of the Water A B, it will sink a fourth Part of its Bulk, and push over the Top of the Jar some Water into the cylindrick Dish C E. Removing the Cube, the Surface of the Water in the Jar will fall down to *a b*, and leave the Space at Top, A *a b* B, empty. Put the Cube into the Scale F of a Balance at *d*, and pour Water into the opposite Scale G, till it æquiponderates with the Cube. That Water pour'd into the Jar, just fills up the Space A *a b* B, which shews that it is equal in Bulk to the immers'd Part of the floating Cube, filling up the Space which that Part had emptied. N. B. *One might also have found the Water forc'd out into the Dish* C D *to be equal in Weight to the Cube; but it does not answer so well in the Experiment, because Allowance must be made for the Water sticking to the Outside of the Jar, and to the Inside of the Dish: otherwise the Quantity of Water forc'd out, and that pour'd in, would be found exactly equal——weighing each an Ounce, as well as the Cube in this Experiment.*

Corollary.

Hence follows that the Water, which a Ship, Barge, or Boat draws, is equal in Weight to the Vessel with all its Load and Tackling; that is, a Bulk of Water equal to the immers'd Part of the Ship weighs as much as the whole Ship, and all in it: so that it is possible for a Barge laden very deep, such

Lect. IX. ſuch as a Barge for Corn, to ſwim very well in ſalt Water, and ſink at once, when it comes into freſh Water. If the Barge B (*Fig.* 7.) is immers'd in Water (or draws Water) as far as W W, a Piece of Water, as W Z W, weighs as much as the whole Barge B Z, and all the Goods it carries. Now let us ſuppoſe this Barge to be laden with Corn at *Amſterdam*, to go to *Rotterdam*, as much as it is able to carry, or till the Water-Line becomes L L: I ſay, that as ſoon as this Veſſel goes out of the Salt Canals into the freſh Water Canals, it will ſink down; becauſe a Bulk of freſh Water L Z L, not being ſo heavy as the ſame Bulk of ſalt Water, the imaginary Surface I S, in the freſh Water that ſupports it, cannot ſuſtain the Veſſel, which is as heavy as the like Bulk of ſalt Water; that is, between a 30th and a 40th Part heavier: the Veſſel therefore ſhould ſink deeper to have a bigger Part immers'd; but being ſuppoſed already juſt even with the Surface of the Water, it can ſink no lower without taking in Water, and going to the Bottom. To prevent this, before you go out of the ſalt Water into the freſh, ſome of the Lading muſt be taken out, till the Veſſel emerges, (a 30th Part, for example) and the Water-Line becomes *m m*; then going into freſh Water, the Barge will only ſink down to L L, and go no lower, the Bulk *l* Z *l* of freſh Water being equal in Weight to the Bulk *n* Z *n* of Salt Water.

Plate 18. Fig. 7.

Corollary 2.

Hence follows alſo, that a great Ship will float as well in a Dock as in the open Sea, provided the Dock has the ſame ſalt Water. Nay, if it was poſſible to have the Dock in which the Ship is, to be of the ſame Shape as the Ship, with only a Space of $\frac{1}{4}$ of an Inch round the Ship's Sides and Bottom, the ſmall Quantity of Water filling that Space would float the Ship; by which means a Ton or two of Water will ſuſtain a Ship of 1000 Ton. This may be illuſtrated by the following

Experiment 6. *Plate* 18. *Fig.* 8, and 9.

Plate 18. Fig. 8, 9.

Take the Glaſs Jar A B, which holds about two Quarts, and weighs about a Pound, and having put into it the Weight B of two Pounds, ſet it a-float in the great Veſſel I K about half full of Water; then obſerving how far the Jar A B ſinks below the Surface of the Water S S, make a Mark on it, as *s s*. Take out the Jar A B, ſtill leaving in it the Weight B, and let it down into the Jar C D E of *Fig.* 9. which is ſo little bigger than the Jar A B, as but juſt to take it in, leaving about the 40th Part of an Inch between the Jars, and about two Ounces of Water being in the Bottom of the outer Jar, even with the Line L L. The Jar A B will ſink down in the Jar C D E, till the Water from the Bottom

Bottom riſes up to *s s*, the Mark in the Jar A B, and there the Water will reſt, and the ſaid Jar float at the ſame Height, as it did in the great Veſſel I K, *Fig.* 8. This ſhews, that it is not the Quantity, but the Height of the Water which floats the ſwimming Veſſel. This may be compar'd to the Water-Bellows * made uſe of for explaining the Hydroſtatical Paradox, ſee *Plate* 10. *Fig.* 1. where L *p*, the Height of the Water in the Tube L *p* I, muſt be multiplied into the Baſe of the Water in the Bellows, to find the whole Force of the Water puſhing upwards; which is found here by multiplying S E, the Height of the cylindrick Shell, into the Baſe of the Water at E. This Product is equal in Bulk to the immers'd Part of A B, and in Weight to that Jar, with its contain'd Weight B.

* L. 7. No 17. Plate 10. Fig. 1.

COROLLARY 3.

HENCE likewiſe may be found a Method for finding the Weight, Bulk, and ſpecifick Gravity of any Body ſpecifically lighter than Water, be it ever ſo irregular, without meaſuring or weighing the Body itſelf: which is done thus. The Body being laid on a full Veſſel of Water, drives out a Quantity of Water, which weigh'd, gives the Weight of the Body. The Body puſh'd down, ſo as to be immers'd in the Veſſel full of Water, drives out a Quantity of Water, which meaſur'd, gives the ſolid Contents of the Body. Then as the Weight of the laſt Quantity of Water : is to the firſt : : ſo is the ſpecifick Gravity of Water : to the ſpecifick Gravity of the Body.

THESE Conſiderations naturally lead us to that Propoſition which is call'd *Archimedes*'s Propoſition.

8. IT is reported, that *Hiero* King of *Syracuſe*, having given a Workman a certain Quantity of Gold to make him a Crown, the Workman allay'd the Gold with Silver, (as it was neceſſary to allay it either with Silver or Copper) but put in a greater Quantity of Silver than was needful, cheating the King of ſo much Gold. When the Crown was brought home, the King ſaw he was cheated, and wanted to know how much; but, as he liked the Workmanſhip of the Crown, he was unwilling to have it melted, or any way defaced : therefore he deſired *Archimedes* to find out how much Gold, and how much Silver was in the Crown. *Archimedes* having a long time ſtudied in vain how to ſolve this Difficulty, at laſt found it out by chance; for going into a Bathing-Tub that was full of Water, he obſerv'd that the Water that his Body forc'd to run over, muſt be equal to the Bulk of his Body, and therefore that he might find the Bulk of the Crown (which was the firſt thing he wanted) by

Lect. IX. by plunging it in a Veſſel full of Water, and meaſuring the Water ſpill'd. He was ſo pleas'd with this Thought, that, forgetting he was naked, he jump'd out of his Bath, and ran about the Houſe, crying out ἑυρηκα, ἑυρηκα, (*I have found it*) as ſome affirm, who are pleas'd when they can ſhew that Mathematicians and Philoſophers are often *abſent:* but others ſay that he offer'd a Hecatomb to *Jupiter*, for having inſpir'd him with the Thought. But thus he proceeded in his Enquiry. He took a cylindrick Veſſel, as A B, (*Fig.* 10.) big enough to hold the Crown, and Water above it; and having fill'd it up to a certain Mark, as W W, and made other Marks from thence upwards, to know how much, or what Quantity of Water ſhould be rais'd above W W, by immerging Bodies in the Water, (which was a better way than making the Water run over the Top of the Veſſel, which could not, when thus ſpill'd, be ſo exactly meaſur'd:) Then having made a Ball of Gold G, exactly of the Weight of the Crown, and likewiſe a Ball of Silver S, exactly of the Weight of the Crown, he conſider'd, that if the Crown were all of Gold, the Ball of Gold would be of the ſame Bulk as the Crown; and therefore being immers'd, would raiſe the Water juſt as high as the Crown immers'd: but if the Crown were all of Silver, the Ball of Silver being immers'd would raiſe the Water no higher than the Crown immers'd: and if the Crown was of Gold and Silver mix'd in a certain Proportion, that Proportion would be ſhewn by the Height to which the Crown would raiſe the Water higher than the Gold, and lower than the Silver. Accordingly, letting down the golden Ball into the Water that ſtood at W W in the Veſſel, it rais'd up the Water to *g g*, the Space *g g* W W containing, for example, a Pint of Water. Then taking out the Gold, he put in the Silver, which rais'd the Water to *s s*, the Space *s s* W W containing two Pints of Water. Then immerging the Crown, it rais'd up the Water to *c c*, the Space *c c* W W containing a Pint and a half. Having made his Obſervations, he reaſoned thus: If the golden Ball raiſes a Pint of Water, and the Silver Ball two Pints; Half the golden Ball will raiſe Half a Pint, and Half the Silver Ball a Pint: then putting together Half the golden Ball, and Half the Silver Ball, they will jointly raiſe a Pint and an half; but the Crown raiſes a Pint and an half; therefore the Crown muſt be half Gold and half Silver. How to do this, let the Proportion of Gold and Silver to each other be what it will, will be ſhewn in the Notes *.

Plate 18. Fig. 10.

* Ann. 2.

9. If two Bodies ſpecifically heavier than Water, but of different ſpecifick Gravities in reſpect to each other, are *in æquilibrio* in the Air; when

when let down into Water, they will lose their *Æquilibrium*, that Body preponderating which has the greatest specifick Gravity. Lect. IX.

PROBLEM.

10. *The specifick Gravity of a Fluid, and of two Bodies, one heavier, the other lighter than Water, being known; how to find in what Proportion of Weight to mix or join them, so that their Mixture of joint Mass shall be of the same specifick Gravity as the Fluid.*

LET us suppose it is requir'd to find how much Cork is needful to join to an human Body weighing 150 ℔. so as to make it of the same specifick Gravity as Water. First let us by proper Experiments find the specifick Gravity of these three Substances, which will be thus express'd comparatively in Numbers. The Body 10. Water 9. Cork $2\frac{1}{4}$. Then let us find how their comparative Bulks of equal Weights must be express'd: and they will be reciprocally the Bulk of the Body 9. The Bulk of the Water 10. The Bulk of the Cork 40. And the Problem will be solv'd by the following Operations. Multiply the Weight of the heavy Body (*viz.* the human Body) by the Number expressing its Bulk, and substract that Product from the Product of the Weight of the said Body; and divide that Difference by the Difference between the Bulk of the Cork, and the Bulk of the Water: and you will have the Weight of Cork requir'd.

$$\frac{\overline{150 \times 10} - \overline{150 \times 9}}{40 - 10} = \frac{150}{30} = 5 = \text{Weight of Cork.}$$

COROLLARY.

HENCE if a greater Weight of the same Cork be added to such an human Body, it will never sink.

SCHOLIUM.

IF the human Body be immers'd no deeper than up to the Neck when the Experiment is made to investigate its specifick Gravity, and a Piece of Cork be found sufficient to make it buoyant in that Situation; this Problem may be of use to find the necessary Weight of Cork to make proper Contrivances to learn the Art of Swimming. See the Notes *, where this Problem is solv'd algebraically two ways. * Ann. 3.

EXPERIMENT 7. *Plate* 18. *Fig.* 11.

TO the String fix'd to the Hook V of the Scale B of a Balance, hang *g*, a round Plate of Lead, and to the String from the other Scale A hang *b*, a round Plate of Brass, if of the same Diameter as the Lead, yet Plate 18. Fig. 11.

 thicker,

Lect. IX. thicker, that it may weigh as much as the Lead. When you let them down into the two Jars of Water E, F, the Lead *g* will preponderate. But now if you reſtore the *Æquilibrium* by adding Weight in the Scale A; the *Æquilibrium* will be loſt again as ſoon as the Bodies are brought out of the Water into the Air.

11. THIS ſhews that Bodies of different ſpecifick Gravities counterpois'd in any Fluid, loſe their *Æquilibrium*, that which is ſpecifically lighteſt over-weighing when remov'd into a lighter Fluid, or a Vacuum *. * Ann. 4.

12. IF inſtead of Lead and Braſs *g* be a good Guinea, and *b* a bad one, which weighs as much, and therefore would deceive you when try'd by the common Gold Scales, (and if it be of baſe Metal plated with Gold, it will alſo deceive upon the Touch-ſtone) when the Guineas are let down into the Water, the good Guinea will over-weigh: becauſe as the bad Guinea has more Bulk, being made thicker, (otherwiſe it would not be heavy enough to paſs in the Gold Scales) it muſt loſe more of its Weight in Water than the good one.

FROM the ſeveral foregoing Conſiderations, it follows, that the Weights that we commonly uſe are not really what they are call'd; becauſe as Air reſiſts, what we call a Pound in the Air, is a Pound and ſo much more as an equal Bulk of Air weighs: that is, if a Pound in a caſt Braſs Weight was *in Vacuo*, it would weigh one Pound and one Grain; becauſe a Grain of Air is equal in Bulk to 3 $\frac{1}{2}$ cubick Inches, which is the Bulk of a Pound Weight in caſt Braſs: and that Grain is added to overcome the Reſiſtance which the nominal Weight loſes in the Air *. * Ann. 5. The ſame is true of all other Weights; but that Nicety is overlook'd in common Uſe.

13. THE Hydroſtatical Balance is an Inſtrument contriv'd for putting in practice what has been ſhewn, and explain'd in the foregoing Propoſition, with which the proper Experiments may be made with great Speed and Accuracy, for making the hydroſtatical Compariſon of Solids with each other, of Fluids with each other, and of Fluids with Solids. This Inſtrument conſiſts of the following Parts, repreſented by the *Figures* 12, 13, 14, 15. of *Plate* 18. Plate 18. Fig. 12, 13, 14, 15.

Fig. 12. A B is a nice Balance turning with a ſmall Part of a Grain. This Balance has a long Examen D, by which one may the more eaſily perceive when the Balance is horizontal, and the Bodies weigh'd *in æquilibrio*.

* Ann. 6. To the little Scale S, by an Horſe-Hair *, hangs underneath it the Glaſs Bubble G, which muſt be ſpecifically heavier than any Liquor

except

except Mercury. At A, the opposite End of the Beam, hangs a Brass Scale E, which is a Counterpoise to the Bubble G, when it hangs immers'd in Water; but when the Bubble hangs out of the Water, a Weight must be laid on E to keep it *in æquilibrio*, which Weight will be equal to what the Bubble lost in Water; that is, to a Bulk of Water equal to the Bubble, which Water we will here suppose to be Rain Water, and to weigh 1000 Grains. The Jar I, in which the Bubble hangs *in æquilibrio*, when it is fill'd with Rain Water, serves to put in successively any Liquor, whose specifick Gravity you would find out. It is no matter how big, or how little the Jar I is, provided the Bubble can descend freely in it without touching the Sides; because of every Liquor that we try, we only compare a Bulk of one Liquor equal to the Bubble with the like Bulk of another Liquor. For example, if we fill I with red Port Wine, the Bubble will sink till we restore its *Æquilibrium*, by putting 10 Grains in the Scale E, which shews that Port Wine is lighter than Rain Water 10 Parts in 1000, or one Hundredth Part. If I had been fill'd with Proof Brandy, 77 Grains must have been plac'd in E to have restor'd the *Æquilibrium*, because Brandy (or Proof Spirits) weighs 77 Parts in 1000, or $\frac{1}{13}$ less than Rain Water. But in a denser Medium G would rise; for example, if I be fill'd with Sea Water, the Bubble becoming too light, 26 Grains must be put into the Scale S, to restore the *Æquilibrium*, which shews that Sea Water is 26 Parts in 1000, or $\frac{1}{38}$ heavier than Rain Water; or that there must be 1026 Quarts of Rain Water to weigh as much as 1000 Quarts of Sea Water.

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Plate 18. Fig. 12, 13.

In order to find the specifick Gravity of Solids, and to compare them with each other, and with Water, or any other Fluid, you must make use of the Parts represented in *Fig.* 13.

K is a Glass Bucket, in which are to be plac'd the Solids to be weigh'd, which, together with its suspending Piece H, is *in æquilibrio* with the above-mention'd counterpoising Scale made use of before.

The Balance A D B is the same as in *Fig.* 12. moveable on its Center C.

Having weigh'd the Solid in Air in the Bucket, putting its counterpoising Weights on the Balance E, write down its Weight; and then weigh it in Water, to find how much it has lost of its Weight: but because not only the Solid to be try'd, but the Glass Bucket itself will lose of its Weight, when immers'd in Water, you must restore to the Bucket the Weight that it loses by being immers'd, that the Body in it alone may be examin'd; and this is done by help of the Piece F, which weighs just as much as a Bulk of Water equal to the Bucket, and being slipp'd on the suspending Piece at H, it not only restores to the Bucket

Lect. IX. what it had lost by being immers'd in Water, but makes a Scale to receive Weights to restore the *Æquilibrium* to the Solid contain'd in the Bucket, and shew how much it has lost of its Weight in Water. *Fig.* 15. shews the Bucket immers'd in Water in the Jar I, with its additional Scale F slipp'd on the suspending Piece H.

EXPERIMENT 8. *Plate* 18. *Fig.* 15.

Plate 18. Fig. 15. A GUINEA, and all the Standard Gold, is about 18 times heavier than Water. Now to examine a suspected Guinea by the Hydrostatical Balance, first weigh it in Air in the Bucket, and it will weigh 129 Grains, which are plac'd in the Scale E; then having put on F over H, and the Bucket with the Guinea in it into the Jar I, (*Fig.* 15.) the Bucket will rise a little out of the Water, on account of what the Guinea loses; but putting 7 $\frac{1}{4}$ Grains into the Scale F, the *Æquilibrium* will be restor'd. 7 $\frac{1}{4}$ Grains are the Weight of a Bulk of Water equal to the Guinea, (which it loses in Water) and dividing 129 (the Grains in a Guinea) by 7 $\frac{1}{4}$, it will be contain'd in it nearly 18 times, which will shew the Piece to be Standard Gold, because Standard Gold is near 18 times heavier than Water: and if you substract 7 $\frac{1}{4}$ Grains from 129, you will have 121 $\frac{3}{4}$ Grains, or the Proportion of 17 to 1, the respective Gravity of the Guinea, or the Weight with which it will descend in Water. If the Guinea had lost 8 Grains or more, that would have shewn the Guinea to have too much Allay; that is, not be of Standard Gold; but if it had lost but 16 $\frac{1}{2}$ Grains, that would have shewn the Guinea to have been of fine Gold, without Allay.

EXPERIMENT 9.

IN the same manner, if you weigh a Piece of Silver in the Air, and it weighs, for example, 100 Grains, then having weigh'd it in Water it loses 10 Grains, you find it to be 10 times specifically heavier than Water, and its respective Gravity as 9 to 1. Thus may be compar'd Ores; that being the richest, which loses least of its Weight in Water. *N. B. Where many Bodies are to be weigh'd hydrostatically, it is best to weigh them all in the Air successively, and set down their Weights, before you begin to weigh them in Water, because it would be troublesome to dry the Bucket every time. Care also must be taken, that no Bubbles of Air adhere to the Bodies weigh'd in Water, which would make them lighter.*

I HAVE added a Contrivance to this Machine to make it more nice, as may be seen in *Fig.* 14. *s s s* are three Screws to set the Foot and Stem upright, and O M is a String and Plummet, whose Point hanging over M, shews when the Piece P C is truly vertical. There is a Piece

E O, which has a Slit to compare with the Examen D of the Balance playing in the Notches C *c*. Lect. IX.

14. There is another way to find the ſpecifick Gravity or Denſity of Fluids; that is, by making them preſs againſt each other in a recurve Tube, becauſe when their Preſſures are equal, their Denſities will be inverſely as their Heights.

Experiment 10. *Plate* 18. *Fig.* 16.

Pour Mercury into the curve Tube A, ſo as to fill the lower Part of it from *b* to *c*, then pour in Water in one Leg from *b* to *e*, and in the other Oil of Turpentine, till both the Surfaces of the Mercury *b c*, be of the ſame Height, which will be when the Oil is up at *c*. Now theſe Heights *b e* and *c d*, being found to be as 87 to 100, will ſhew the inverſe Ratio of thoſe Fluids; that is, That the Denſity of Water : is to the Denſity of the Oil of Turpentine : : as 100 (the Height of the Oil of Turpentine) : is to 87, (the Height of the Water.) N. B. *This may alſo be deduc'd from what was ſaid in* Lect. 7. N° 11, 12, and 13. Plate 18. Fig. 16, 17, 18.

Scholium.

Here we muſt take care not to make a Miſtake, and think, that becauſe in this Experiment the Bulks of the Fluids being inverſely as their Denſities, and conſequently their Quantities of Matter equal, it follows, that to have an equal Preſſure upon the Surfaces of the Mercury, the Quantity of Matter in the different Fluids muſt be equal. It only happens ſo when the two Sides of the Tube have the ſame Bore; therefore we muſt not draw a general Concluſion from this particular Caſe; for the Mercury will be equally preſs'd, (by altering the Bore of the Tube) when the Fluids have their Bulks equal or unequal in any Proportion. It is the Heights that muſt determine the reſpective Denſity of the Fluids, which they will always inverſely repreſent, the Preſſure being always as thoſe Heights, as has been ſhewn*. See *Fig.* 17. where the Bulk of the Water is equal to that of the Oil; and *Fig.* 18. where the Bulk of the Oil is 10 times greater than that of the Water.

* L. 7. N° 11, 12, and 13.

The

The following TABLE *of the different specifick Gravities of several Solids and Fluids, is calculated from Experiments accurately made with the Hydrostatical Balance.*

A Cubick Inch of	Weighs in Ounces Troy.	In Ounces Averdupoids.	The comparative Weight of the Substances.
Fine Gold	10,359273=	11,365602—	19639
Standard Gold	9,962625=	10,930422—	18887
Quick-silver	7,384411=	8,101753—	13999
Lead	5,984010=	6,553885—	11325
Fine Silver	5,850035=	6,418324—	11090
Standard Silver	5,556769=	6,096569—	10534
Rose Copper	4,747121=	5,208369—	9000
Plate Brass	4,404273=	4,832116—	8344
Cast Brass	4,272409=	4,630300—	8001
Steel	4,142127=	4,544505—	7835
Common Iron	4,031361=	4,422979—	7642
Block Tin	3,861519=	4,236638—	7320
Diamond	1,793357=	1,834536—	3400
Fine Marble	1,429411=	1,568859—	2710
Common Glass	1,360841=	1,493037—	2579
Alabaster	0,988456=	1,084477—	1873
Dry Ivory	0,962083=	1,055542—	1823
Dry Box-Wood	0,543282=	0,596057—	1021
Sea Water	0,542742=	0,594894—	1037
Common clear Water	0,527458=	0,57869 —	1000
Red Wine	0,523766=	0,574646—	992
Proof-Spirits, or Brandy	0,489268=	0,536796—	927
Sound dry Oak	0,489008=	0,536569—	927
Lint-seed Oil	0,491591=	0,539345—	931
Oil Olive	0,481569=	0,528350—	911
Air	$\frac{2}{7}$ of a Grain= or 0,000595	0,000667—	1,17 or 0,285 Grains.

THO' the Use of this Table is obvious from what has been said, yet as my Design in this Course is rather to be too circumstantial than leave any thing unexplained, I shall give an Example or two of its Application.

1. SUPPOSE the Flat of a Roof of an House is to be cover'd with Lead of the Thickness of the 10th of an Inch, (the Length being 40 Foot, and the Breadth 35) it is requir'd to know what the Lead will weigh that is requir'd to do it. First find the Area of the Roof, which is 1400 square Feet, (because 35 × 40 = 1400) then considering that as one Foot,

Foot, which contains 144 square Inches, is but $\frac{1}{10}$ of an Inch thick, it must be divided by 10, to give its Contents in cubic Inches; that is 14,4: and finding in the Table 6,553885 for the Weight of a cubic Inch of Lead, multiply it by 14,4 to have 94,376912 for the Weight of one square Foot of the Lead requir'd, which again multiplied by 1400, you will have 132127,6768 Ounces Averdupoids, which make 68 Hundred three Quarters and six Pounds, for the Weight of all the Lead. Lect. IX.

If you would know what would be the Weight of Copper $\frac{1}{24}$ of an Inch thick to cover this Roof, you will easily find it by two easy Operations of the Rule of Three.

As 11325, the comparative specifick Gravity of Lead:
To 9000, the specifick Gravity of Copper::
So is 68 C. and $\frac{3}{4}$, and 6 ℔. or 68,81:
To the Weight of Copper as thick as the Lead; or 54,78 Hund.

Then as the Copper is but $\frac{1}{24}$ of an Inch thick, I say,
As $\frac{1}{10}$ of an Inch:
Is to $\frac{1}{24}$::
So is 54,78 Hundreds:
To 22 Hundred $\frac{3}{4}$, and 7 Pounds.

If you would cover this Roof with Oak, an Inch thick, I say,
As 9000, the specifick Gravity of Copper:
To 927, the specifick Gravity of dry Oak::
So is 22 C. $\frac{3}{4}$, and 7 ℔:
To 2,35 C. or 2 C. 1 Quarter, and 11 ℔.

But as the Oak is 24 times thicker than the Copper, this Number must be multiplied by 24, for the Weight of the Oak, *viz.* 56 C. 1 Quarter, 16 ℔.

Having some Years ago made some Experiments at *Bath* with Dr. *Oliver* upon the specifick Gravities of the Waters; I have, at the Desire of some Friends, subjoin'd them here.

The Bubble of my hydrostatical Balance weigh'd in Air	2035 Grains.
In New-River-Water ———	1260
Bulk of Water = to Bubble ——— —	775

The Bubble in the following Waters weigh'd more or less, as below.
In Rain $\frac{1}{2}$ Gr. less.
Hot Bath unseal'd, 1 Gr. +
King's Bath unseal'd, + 1 $\frac{1}{2}$.
Hot Bath seal'd at the Pump, + 1.
King's Bath seal'd at the Pump, + 1.
Hot Bath hot from the Pump — 3 $\frac{1}{2}$ Gr.
Bristol Water, + $\frac{1}{4}$ Gr.

Roade

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Roade Water + 1 Gr.
Holt Water + 2 Gr.
Broughton Water + 3 Gr.
King's Bath hot from Pump — 3½ Gr.
Cross Bath + ½ Gr.

Of the Action of Air upon Water by Condensation and Rarefaction in artificial Fountains, and some other Machines.

EXPERIMENT 9. *Plate* 19. *Fig.* 1.

Plate 19. Fig. 1, 2, 3.

15. THE Bottle A full of Holes at the Bottom dipped in Water and half fill'd, the Water will not run out again, if the Thumb be held on its Mouth B. The Reason is, that the external Air pressing against the Holes as much as the Air in the Bottle pushes upon the Water; the Water can't fall without rarefying the Air in the Bottle by augmenting its Space: then it would be too weak for the external Air pushing against it; but if the Water had some Depth, suppose a Foot, as from W to X the Bottom of the Bottle, it would begin to run till the Air was rarefied $\frac{1}{32}$ Part; because as an Height of Water equal to 32 Foot, has as much Force of Pressure as the Air, (whether it acts by its Spring or its Weight) the Height of one Foot of Water is equal to $\frac{1}{32}$ Part of the Force of the Air, and this added to the Force of the Water in the Bottle makes it $\frac{1}{32}$ Part stronger in Force, than the outward Air that resists to the issuing Water: But when the Air in the Bottle has encreas'd its Dimensions $\frac{1}{32}$ Part by the loss of so much Water, it has lost $\frac{1}{32}$ Part of its Force, which being supplied by the Pressure of the Water, added to its own diminish'd Pressure, it is *in æquilibrio* with the Resistance of the external Air, and all things are at rest.

EXPERIMENT 10. *Plate* 19. *Fig.* 2, *and* 3.

16. FILL the Glass Jar A B, holding about a Pint, nearly full of Water, and having cover'd its Mouth with a Piece of Paper as *d c*, press the Palm of one Hand hard on the Paper, whilst with the other Hand H you overturn the Glass; then (when the Paper *d c* is in an horizontal Position under the Mouth of the inverted Glass) the Pressure of the Air upwards will keep the Water suspended, which it wou'd not do without the Paper, because the whole Column of Water becoming one Body, acts uniformly on the resisting Air, whose Action upwards is just equal to the Action of the Spring of the Air above A B, together with the Weight of the Columns of Water between A B and *d c*. Now, if the Paper was away, the Water wou'd not be sustain'd, because it wou'd

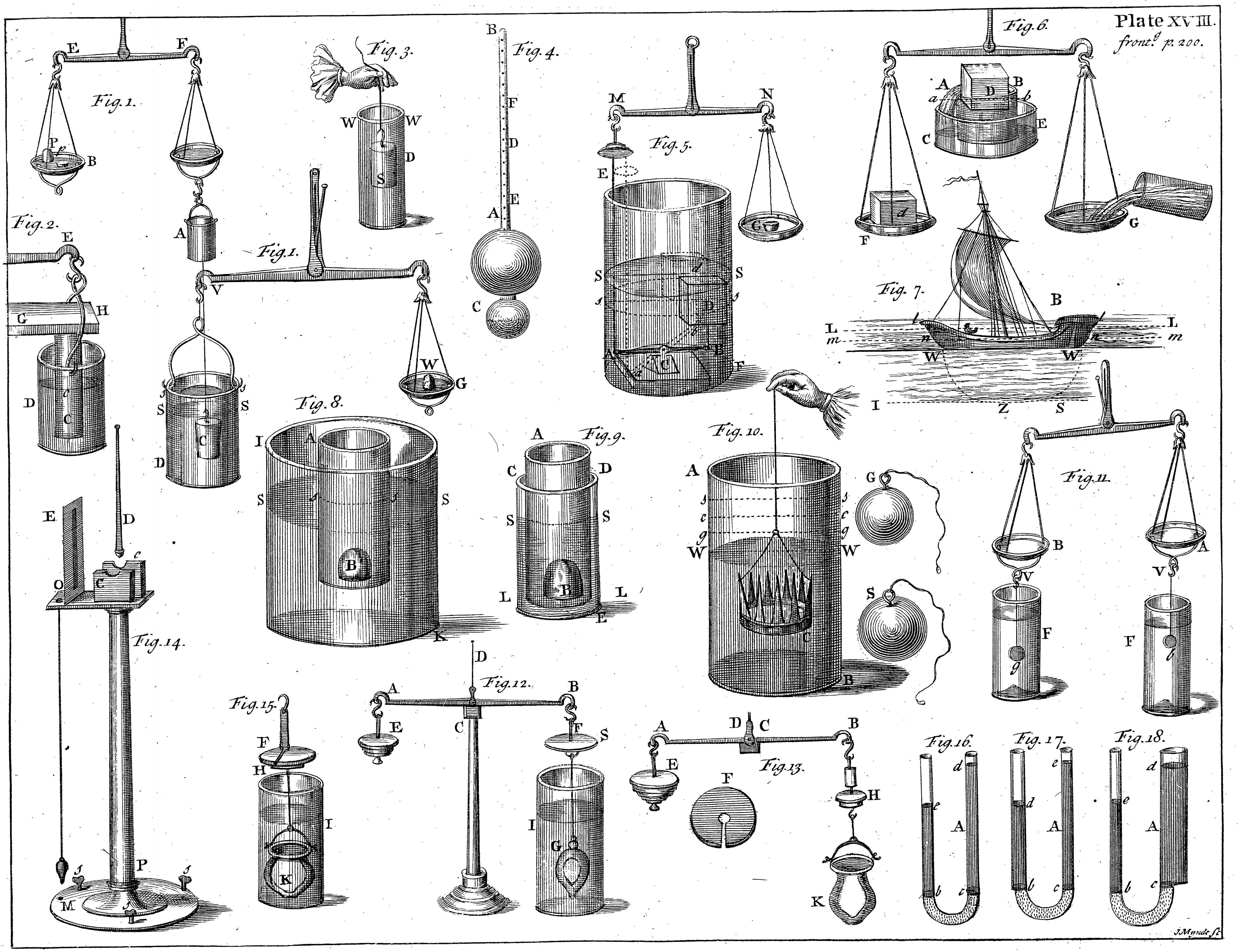
Plate XVIII.
front.g p. 200.
Fig. 1.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
J. Mynde fc.

wou'd be next to impoſſible to hold the Veſſel ſo even, as to have all the Columns of the Water of the ſame Height; which wou'd occaſion ſome of the Water to come down on one ſide as B C, whilſt the reſt of the Water went up at *d* A. But the Bottle of *Fig*. 3. won't ſpill its Water, if it be inverted and the Mouth *e f* is horizontal, provided the Mouth be narrow. For if a Drop of Water being ſuppoſed between *e* and *f*, the Attraction of Coheſion reaches from *e* and *f* to that Drop, there will be form'd a Skin of Water inſtead of the Paper in the other Experiment. Lect. IX. Plate 19. Fig. 3.

N. B. If the Mouth of the Bottle be but a quarter of an Inch Diameter, the Water will not run out, tho' the Bottle ſhould be inclin'd. But if the Bottle's Mouth be of near three quarters of an Inch Diameter, it will only hold Water, when it is inverted in an erect Poſition; becauſe if the Surface of the Water in the Bottle, inſtead of being in the Line *d b*, ſhou'd be in the Line *a b*, the Air puſhing up againſt the Mouth *e f*, would be acted upon unequally by the Columns of Water at *a e* and at *c f*; that it wou'd yield at *f* to the Columns *c f*; but overcome the ſhorter Columns at *e a*; ſo as to riſe into the Bottle at *a*, whilſt the Water came out at *e*. Plate 19. Fig. 4, and 5.

17. Hence it appears why the artificial Fountain of *Plate* 19. *Fig*. 4. (which may be ſet up on either of its Ends) after it has plaid out all its Water in a Jet thro' the ſpouting Pipe E, plays again afreſh thro' the Spout I, when you have turn'd it over like an Hour-Glaſs; and ſo as often as you pleaſe. A little Attention to the Figure will ſhew the Make of it. The Water contain'd in the Cavity A F H runs down the curve Pipe C D E, and ſpouts up thro' the Jet E by the Preſſure of the Column of Water C D. But unleſs the Pipe G F was open at G, to let the Air run up to F, and preſs at top of the Surface of the Water in the Cavity A, the Water could not run down and ſpout at E. There is ſuch another Pipe as G F at K, belonging to the Cavity B, thro' which the Water of the Jet receiv'd in the Baſon ſupplies the Cavity B, whilſt the Fountain ſtands on the end B; but when the Fountain is inverted, it ſupplies B with Air to let the Water deſcend in the Direction G H I, I becoming the ſpouting Pipe.

18. Upon theſe Principles depends alſo the alternate running and ſtopping of the Fountain of Command of *Plate* 19. *Fig*. 5. C A E is a Receptacle, or Veſſel of Water cloſe from the Air's Entrance, except thro' the Pipe G F, when the Cock C (by which it was filled) is ſhut. There is another Pipe E D H B which goes from the Bottom of the Wa-

Lect. IX. Plate 19. Fig. 6, 7.

ter to the Jet B in the Bason DB, but is stopped by the Cock H. At the lowest Part of the Bason DB, there is a small Hole at I to let the Water of the Bason DB run into the Bason GH under it: there is also a small triangular Hole or Notch in the Bottom of the Pipe FG, at G. Turn the Cock H, and the Fountain will play for some time, then stop, then play again alternately for several times together. Knowing those Times of playing and stopping a little beforehand, you may command it to play or stop, which has given it the Name of Fountain of Command. The Cause of playing and stopping is this: The Water coming down the Pipe EDHB wou'd not come out at B, for the Reasons before given, if the Air SS above the Water was not supplied as it dilated: Now it is supplied by the Pipe GF, which takes it in at the Notch G, and delivers it out at F; but after some time the Water which has spouted out at B, falling down into the Bason DB, rises high enough to come above the Notch G, which stops the Passage of the Air, so that the Air SS above the Water in the Vessel CAE cannot sufficiently press for want of a Supply, and the Fountain ceases playing. This is easily seen by observing the Surface of the Water at G. Now the Water of DB runs down into the lower Bason HG thro' the Hole I, till it falls below the Top of the Notch G, and then the Air runs up into the upper Receptacle again, and supplying the Air at SS, the Fountain plays again. This is seen a little beforehand by a Skin of Water on the Notch G before the Air finds Passage, and then you may command the Fountain to play. The Hole I must be less than the Hole of the Jet, or else the Water wou'd all run out into the lower Bason, without rising high enough to stop the Notch G.

19. The next Fountain AB, *Fig.* 6. is only the same Fountain in large, which was shewn in small in the 7th Figure of the 11th Plate, and explain'd Lect. 7. N° 24. where the Air is condens'd at Top of the Water; only in that it is condens'd by blowing in, whereas in this large one it is compress'd by a Syringe (to be described hereafter) and the Air and Water are retain'd by the Cock C, so that the Fountain cannot play till you open the Cock; then the Water strongly press'd by the condens'd Air at SS, goes thro' the Pipe O and the Ajutage *b* with great Force, in Jets of several Figures according to the Spouting-Pipes put on at *b*.

20. As here the Air is compress'd by a Syringe, in the Fountain, *Plate* 19. *Fig.* 7. contrived by *Hero* of *Alexandria*, the Air being only compress'd by the conceal'd Fall of Water, makes a Jet, which seen

for

for a while, is look'd upon as a perpetual Motion by the Ignorant, who think that the ſame Water that fell from the Jet riſes again. Lect. IX.

The Boxes C E and D Y X being cloſe, you ſee only the Baſon A B W, with a hole at W, into which the Water ſpouting out at B falls; but that Water going down the hole W, does not come up again at W, as it ſeems to the Ignorant; for it runs down thro' the Pipe W X into the Box D Y X, from whence it drives out the Air thro' the aſcending Pipe Y Z into the Cavity of the Box C E, where preſſing upon the Water that is in it, it forces it out thro' the Spouting-Pipe O B, as long as there is any Water in C E: ſo that this whole Play is only whilſt the Water contain'd in C E having ſpouted out, falls down thro' the Pipe W X into the Cavity D Y X. The Force of the Jet is proportional to the Height of the Pipe W X, or of the Boxes C E and D Y above one another. The Height of the Water meaſur'd from the Baſon A B W to the Surface of the Water in the lower Box D Y X is always equal to the Height meaſur'd from the top of the Jet to the Surface of the Water in the middle Cavity at C E. Now, ſince the Surface C E is always falling, and the Water in D Y always riſing, the Height of the Jet muſt continually decreaſe, till it is ſhorter by the Height of the Depth of the Cavity C E, which is emptying, added to the Depth of the Cavity D Y which is always filling: and when the Jet is fallen ſo low, it immediately gives over. *N. B. The Air is repreſented by the Points.* The way to prepare this Fountain for playing (which is generally done privately before it be expoſed to View) is this: Firſt, pour in Water at W, till you have filled the Cavity D X Y; then turn the Fountain over, and the Water will run from the Cavity D X Y into the Cavity C E, which you will know to be full, when the Water runs out at B held down. Set the Fountain up again as if nothing had been done to it. When you wou'd make it play, pour in about a Pint of Water into the Baſon A B W, and as ſoon as it has filled the Pipe W X, the Fountain will play, and continue to do ſo as long as there is any Water in C E. You may then pour back the Water left in the Baſon A B W into any Veſſel, and invert the Fountain, which being ſet upright again, will be ſet a playing by putting back the Water pour'd out into A B W, and ſo *toties quoties*.

Plate 19. Fig. 7, 8, 9.

21. The Fountain of *Fig.* 8. is upon the ſame Principle and of the ſame kind; but having double the Number of Pipes and conceal'd Cavities, it plays as high again. You muſt examine *Fig.* 9. to ſee its hidden Cavities and Pipes. The Baſon is A; the four Cavities are B, C, D, and E, from which the Water thro' the Pipe F G ſpouts up to double

Lect. IX. Plate 19. Fig. 9, 10.

the Height of the Fountain, the Air at E which drives it being doubly condens'd. The Water going down the Pipe 1, (suppose it to be 3 Foot long) condenses the Air that goes up into the Cavity C thro' the Pipe 2, so as to make it $\frac{1}{10}$ stronger than the common Air: then the Water which falling in the Pipe 3 from C to D, is capable by the Height of its Fall to condense the Air at E, so as to make it $\frac{1}{10}$ stronger, being push'd at C by Air already condensed into $\frac{1}{10}$ less Space, causes the Air at E to be condens'd twice as much; that is, to be $\frac{1}{5}$ stronger than common Air, so that it will make the Water at G spout out with twice the Force, and go to twice the Height that it would do, if the Fountain had been of the Make of the former.

The way to prepare this Fountain for playing, is, to turn it upside down, and taking out the Plugs *g*, *h*, to fill the two Cavities C and E, and having shut the Holes again, set the Fountain upright, and pour some Water into the Bason A, and the Jet will play out at G. But the Fountain will begin to play too soon. So that the best way is to have a Cock in the Pipe 3, which being open whilst you fill the Cavities C and E, and then shut again before you set up the Fountain again, will keep the Water thrown into the Bason from going down the Pipe 1, and that of the Cavity C from going down the Pipe 3, by which means the Fountain will not play before its Time, which will be as soon as you open the Cock.

Plate 19. *Fig.* 10.

22. Another way to make Fountains, is by the Rarefaction of Air in the following manner. A B and C D are two Pipes fix'd to a Brass Head C to screw into a Glass Vessel E, which having a little Water in it, is inverted till the Pipes are screw'd on; then reverting it suddenly, so as to put A the lower end of the Spouting-Pipe A B into a Jar of Water A, and the lower End of the descending-Pipe C D into a receiving Vessel D, the Water will spout up from the Jar A into the tall Glass Vessel E, from which it will go down at the Mouth C, thro' the descending Pipe C D into the Vessel D, till all the Water is out of A (making a Fountain in E) has emptied it self into D.

The Reason of the Play of this Fountain is this:

The Pipe C D being 2 Foot 9 Inches long, lets down a Column of Water, which rarefies the Air $\frac{1}{12}$ Part in the Vessel E, where it presses against the Water spouting at B with $\frac{1}{12}$ of the Force that the Water is push'd up the Hole A, by the Pressure of the common Air on the Water in the Vessel A; so that the Water spouts up into E (when the Air is rarefied $\frac{1}{12}$) with the Difference of the Pressure of the Atmosphere and the aforesaid rarefied Air; that is, of 33 to 2 $\frac{3}{4}$. This would raise the

the Water 2 Foot 9 Inches; but the Length of the Pipe A, 9 Inches, being deducted, the Jet will only rise 2 Foot. Lect. IX.

N B. *This may be call'd a Syphon Fountain, where* AB *is the* driving Leg, *and* CD *the* issuing Leg. Plate 10. Fig 11.

23. There are many more artificial Fountains made upon these Principles, but what we have explain'd may be sufficient, when we have added to it the Description of one that I invented to play by the Spring of the Air, increas'd by the Heat of the Sun; which also serves for a Dial at the same time.

Plate 19. *Fig.* 11.

GNS is a hollow Globe of thin Copper of 18 Inches in Diameter, supported by a small inverted Bason, standing on a Frame with 4 Legs ABC, which have between them at the Bottom a large Bason of 2 Foot Diameter. Along the Leg C comes a conceal'd Pipe, going from G the Bottom of the Inside of the Globe, which Pipe comes along HV to join in an upright Pipe *u* I, to make a Jet at I. The short Pipe I *u* going to the Bottom of the Bason, has a Valve at V under the horizontal Part H *u*, and another Valve at V, above the said horizontal Pipe under the Cock at K. The North Pole N has a Screw to open an Hole whereby to fill the Globe with Water. Things thus prepar'd, and the Globe half fill'd with Water, let the Machine be set in a Garden, and the Heat of the Sun rarefying the Air as it heats the Copper, the Air will press hard upon the Water, which coming down the Pipe GCHVI will lift up the Valve V, but shut the Valve *u*, and the Cock being open; spout out at I, and continue to do so for a long time, if the Sun shines, and the Ajutage be small. At Night, as the Air condenses again by the Cold, the outward Air pressing into the Ajutage I, will shut the Valve V, but pressing on the Bason D *u* H, it will push up the Water which has been play'd in the Day-time, thro' the Valve *u*, and the Pipe *u* HG into the Globe, so as to fill it up again to the same Height that the Water was at first, and the next Sunshine will cause the Fountain to play again, &c. The Use of the Cock is to keep the Fountain from playing till the Time of Day that you think proper. A small Jet will play six or eight Hours. If the Globe be set for the Latitude of the Place, and rectified before it be fixed, with the Hour-Lines or Meridians drawn upon it, the Hours mark'd, and the Countries painted on, as in the common Globe, it will be a good Dial, the Sun shining upon the same Places in this Globe, as it does upon the Earth itself.

Expe-

Experiment ii. *Plate* 19. *Fig.* 12.

Plate 19. Fig. 12.

24. In the tall narrow Jar A E full of Water, the Glass Bubble B swims at top; but if it be press'd down with a long hook'd Wire below the Line L L, it goes down to D at the Bottom and stops there: If it be push'd down gently to the Line L L, it will continue there, (at least for some Time;) if it be not push'd quite down so low as LL, it will come up again and stay at Top; and if, when at the Bottom, it be rais'd up from D to any Height below L L, it will go down again, becoming thus successively, specifically heavier, specifically lighter, and of the same specifick Gravity as Water. The Reason of the Change is this: The Bubble has its Stem open at Bottom, in which the Water rising more or less, alters its specifick Gravity. When the Bubble stands at B, the Water is only up at *b* about an Inch in the Stem, and the Bubble being a little lighter than Water, just appears with its Top above the Surface; where it continues, because the Air in it, by its Spring endeavours as much to keep the Water from rising higher in the Stem, as the Weight of the Atmosphere endeavours to push it in: and without the Water rising or falling in this Stem, the Bubble cannot alter its specifick Gravity so as to become heavier or lighter. But when you push the Bubble down, the Depth of the Water from A adds to the Pressure of the Atmosphere, which now overpoising, must compress the Air in the Bubble and cause it to recede into less room, which it cannot do without admitting more Water, which makes it heavier in proportion. When the Bubble is at L L, by help of the additional Pressure of the Height of Water A C, Water is risen in the Stem up to *c*; for Example 3 Inches, and then the Bubble is of the same Gravity as Water, and continues in that Place. When the Bubble is push'd down a little lower, the Water rising higher in the Stem, because the Air in the Bubble recedes as it is more press'd, the Bubble being now made heavier than Water, descends, and the Water in the Stem rises higher, and makes the Bubble increase in Weight, as the Height or Depth of the Water in the Jar encreases, till the Water comes into the Bubble it self, as it appears at the Bottom at D. If you suppose the Jar 2 Foot high, the Air in the Bubble at D is condens'd $\frac{1}{16}$ Part; but it cannot restore it self to the same Tenor as the outward Air, because the outward Air acts against it with an additional Pressure of a Column of Water 2 Foot high, whilst the Bubble continues at D: But if you raise up the Bubble to C, the Air in the Bubble expands itself so as to be only $\frac{1}{32}$ Part denser than the outward Air, and then it makes æquilibrium with the outward Air, whose Pressure is now help'd only by one Foot

of Water. Now, in that Expansion of the Air of the Bubble, the Water in it is push'd out till it comes to *c* in the Stem, in which Case the Bubble with its Water being of the same Weight as an equal Bulk of Water, continues in its Place. If the Pressure against the Air in the Bubble be still diminish'd, by diminishing the Height of the Water A C, which gave the additional Pressure to the Atmosphere, the Air in the Bubble will expand itself yet more, and thereby drive more Water out of the Stem of the Bubble, whereby the Bubble becoming still lighter will go to the Top, where it will remain. As you may see the Water in the Stem of the Bubble rise as the Bubble goes down, and sink as it comes up, this Phænomenon needs no farther Explanation. Lect. IX.

EXPERIMENT 12. *Plate* 19. *Fig.* 13.

25. If a Bubble made a very little lighter than Water was seal'd hermetically, so that it could not alter its specifick Gravity, yet it might rise and sink in Water as the Water should become more or less dense by Cold and Heat. Take six small Glass Bubbles with small Stems, and by putting Water in them, and then sealing them hermetically, make them all lighter than cold Water, and lighter than each other, but so as the lightest may sink in Water, when it is as hot as the Sun can warm it. Putting all these Bubbles in a Jar of cold Water, and setting it in the Sun, they will sink one after another, as the Water grows warm; because the Medium becoming less and less dense, the heaviest Bubble must sink first, *&c.* This may be call'd an hydrostatical Thermometer; and such an one was made at *Florence.* Plate 19. Fig. 13, 14.

26. About 32 Years ago the Reverend and Learned Mr. *John Caswell*, then Professor of Astronomy in *Oxford*, propos'd to me the following hydrostatical Problem.

Having two Glass Bubbles, as A *and* B, (Fig. 14.) *in a Jar of Water, one swimming at top of the Water, and the other lying at bottom: how to contrive, by pouring in more Water, as from the Vessel* I, *to make the said Bubbles change Places, so that* A *shall come up to the Surface at* a, *and* B *go down to the Bottom at* b. I found it out, and made the Experiment; but I refer the manner of doing it to the Notes *; that the Reader may try to find it out before he has it explain'd. * Ann. 7.

27. If A, instead of being a Glass Bubble, had been a Portion of a Fluid specifically lighter than the Fluid E D, in the Jar, and B a Portion of a Fluid specifically heavier, they would not have rested in those Places; but, being left to themselves, would have changed places, the one going

Lect. IX. going up, and the other coming down, for Reaſons already given in Lect. 7 *. But this will appear very plain by an Experiment.

* N° 8, 9, 10, 11.

EXPERIMENT 13. *Plate* 19. *Fig.* 15.

Plate 19. Fig. 15.

THE Jar A being fill'd with red Wine as far as *p*, invert into it the Bottle of Water W, and hold it with its Mouth juſt under the Surface *p*; then you will immediately ſee the Wine riſing up like Smoke in the Neck of the Bottle, thro' the Water, and ſettling itſelf at top of the Water at *u*. The Water in the mean time comes down thro' the Wine, and goes to the Bottom of the Jar at P. You can't indeed ſee it come down thro' the Wine; but that it does ſo ſoon, appears, becauſe the Liquor loſes its Colour, beginning at the Bottom at P, and ſo becoming tranſparent upwards by degrees.

28. THE riſing Fluid would ſoon come down again, if that Fluid in which it moves alter'd its ſpecifick Gravity, becoming much lighter. The Motion of Smoke depends upon that Principle. In fair Weather, when the Air is heavieſt, as the Barometer ſhews it, the Smoke riſes out of our Chimneys directly up to a great Height, becauſe the Air being heavier than Smoke, does by its Deſcent make the Smoke aſcend: but in foul Weather, when the Air is lighteſt, the Smoke then being heavier than Air, falls down again as ſoon as it is out of the Chimney. The Reaſon why the Smoke riſes up to the Top of the Chimney then, is, that while it is in the Chimney it is rarefied or expanded by Heat, and during that Expanſion it is ſpecifically lighter than the Air, and conſequently muſt riſe in it; but as ſoon as it is out of the Chimney, it is ſo far condens'd by Cold, as to become heavier than the ambient Air, whereupon it comes down by its greater ſpecifick Gravity, not being beat down by the Wind, as is commonly imagined. Nay, it comes down if the Weather is ever ſo ſtill; and in froſty Weather, when the Air is heavy, tho' the North or North-Eaſt Wind blows hard, the Smoke won't come down. Few Chimneys ſmoke then. But in rainy Weather, and at any other time when the Barometer is low, in all thoſe Chimneys which are ſo built that the Smoke does not keep its Heat quite up to the Top of the Chimney, the Smoke (becoming heavier than Air) comes down again, let the Wind blow from any Point, and the Chimney is ſaid to ſmoke.

PERHAPS it may be objected to this, that in all States of the Air, (that is, whether heavier or lighter) ſome Chimneys that are commanded, ſmoke by the Impulſe of the Wind, and are cured by moveable Heads, that carry out the Smoke the ſame way as the Wind blows. This is true, and the reaſon of the Chimney ſmoking in ſuch a caſe, is,

that

that by the Motion of the Wind the heterogeneous Fluid made up of Air and Smoke, is driven with more Force towards the Fire than the Air below, which has no other Force to carry it towards the Fire, than that which arises from its Difference of Density from that of the Air heated by the Fire.

Lect. IX. Plate 19. Fig. 10, 11, 12.

29. Tho' Wine always mixes with Water in a Glass, when the Wine is put in first, (except sweet Wines, which are often specifically heavier than Water) and very often when the Water is put in first, and the Wine pour'd in after, because as the Wine accelerates its Motion, and goes into the Water, its Parts are attracted by those of the Water, with which they remain entangled; yet if any small Body, as a thin Piece of Bread, or the Piece of Past-board O, (*Fig.* 10.) fix'd to a Stem Q O to hold it, be laid or held on the Surface of the Water W, to receive the Shock of the Wine pour'd in, as from the Bottle B, the Wine will lie at top unmix'd with the Water, as O P. Nay, by pressing the Palm of the Hand on the Top of the Jar, it may be inverted, and the Wine and Water change Places without mixing.

Experiment 14. *Plate* 19. *Fig.* 17.

Making use of the same Pastboard O P, held successively on the several Surfaces of several Liquors, you may pour in successively six different Liquors without their mixing, as Water, Port Wine, Olive Oil, Brandy, Oil of Turpentine, and rectified Spirit of Wine, express'd by the Letters W, P, O, B, T, S, *Fig.* 17. where A expresses the Air at top. But now it is time to return to our rising and falling Bubbles of Glass, (and hollow Images acting upon the same Principles) which we have not fully consider'd yet.

Experiment 15. *Plate* 19. *Fig.* 12.

When the Glass Bubble at D has too much Water; tho' it be rais'd up to the Top of the Jar at A, where the Air in the Bubble, freed from the additional Pressure of the Pillar of Water A B, expands itself, and forces out some Water, yet it will not force enough out to make the Bubble become lighter than Water: the Bubble will go down again, in which case it is said to be drown'd. But by applying the Hand upon the Top of the Jar, so that the Flesh of the Ball of your Thumb may touch the Water, and then sliding the middle of the Palm of your Hand over the Water, you will take off the Pressure of the external Air to what Degree you please, so as to give the Air in the Bubble liberty to expand

Lect. IX. ſo much as to drive out Water enough to make the Bubble ſpecifically lighter than Water, and riſe up to your Hand.

EXPERIMENT 15. *Plate* 19. *Fig.* 18.

Plate 19. Fig. 18, 19. THUS if a little Glaſs Skeleton, whoſe Head is hollow, with a little Hole at the Bottom of it, (being in effect a Bubble) be made heavy enough to be *juſt drowned*; that is, to ſtand at the Bottom of the Jar A E, and Paper, or any other Covering be put about the Bottom of the Jar as far as L L, ſo as wholly to hide the Figure: by preſſing the Top of the Water in the Jar in the manner above-mention'd, and drawing up the Palm of the Hand, the little Skeleton will ſeem to riſe from a Jar having nothing in it. Again, if there be ſo little Water put into the Bubble or Head of the Figure at firſt, that it ſhall be ſo much ſpecifically lighter than Water, that tho' thruſt down to the Bottom of the Water, it ſhould riſe up again of itſelf: the Hand apply'd at top of the Jar may make it go down, and let it up again, ſo that it ſhall riſe and fall at pleaſure. But for that Purpoſe (the Jar being quite full) the Palm of the Hand muſt be firſt apply'd to its Top, and the Fleſh of the Ball of your Thumb ſlipp'd in the Place to increaſe the Preſſure upon the whole Water, and force more Water into the Bubble, *&c.*

EXPERIMENT 16. *Plate* 19. *Fig.* 19.

30. TAKE three or four Glaſs Images made hollow with Holes in their Feet, ſo that Water may be put into them, till they are but a little lighter than Water, (provided they be not heavy enough to be drowned, when they come to the Bottom of the Jar of Water in which they are to be plac'd) then let them be differently pois'd in reſpect of each other, by putting more Water in one than another. Having thus prepar'd them, put them in a Jar almoſt, or quite full of Water, and having tied a wet Bladder over the Mouth of the Jar, by preſſing on the Bladder more or leſs with the Hand, you may command the little Images to go up and down after one another, knowing which is the heavieſt, that requiring leaſt Preſſure, and thoſe that are lighter more in Proportion, and ſlackening the Preſſure the Images will riſe. But what ſeems moſt ſurprizing, is, that you may command the Image that went down laſt to go down firſt, and ſo *vice verſâ*. This is done in the following manner: Let us take, for example, the two Images C and E, whoſe Holes in the Heels muſt be of different Sizes, and let the Image C, having the biggeſt Holes be ſo pois'd, that being lighter than E, it ſhall require a greater Quantity of Water to be preſs'd into it, to make it come down, than E: upon which account it will not come down till after E. But if you preſs hard and

and ſuddenly, C having the biggeſt Holes will take Water enough to make it ſink, before E (tho' it requires leſs Water) has taken its ſufficient Quantity to ſink it; becauſe tho' that Quantity be leſs than what C wants, yet the Smallneſs of its Holes will not admit it ſo ſoon. There is alſo a way of making the Images turn round, which can only be done with ſuch Figures as have the Holes in them looking ſideways; as, for example, the Image D having an Hole in the Tail; when it is at D, if you ſuddenly eaſe the Preſſure, the Air in the Image will force the Water out in the Direction *m n*, which will make the Image move round in the Direction *n m*; becauſe the Air in the Image endeavouring to expand itſelf every way, preſſes equally towards *o* and *m*; but the Preſſure towards *m* being diminiſh'd, on account of the Hole where the Water ſpouts, (Surface being wanting where the Hole is) the relative Preſſure muſt be greater towards *o*, and carry the Image that way: after the ſame manner that a Rocket riſes by the unequal Preſſure of the expanding Gunpowder, when it wants a fix'd Point below to act againſt *.

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Plate 19. Fig. 19.

* Ann. 8.

31. Of Diving to take up Goods or Treaſure from the Bottom of Rivers, or the Sea, where it is neceſſary to continue ſome time under Water; call'd by ſome, *The Art of living under Water.*

The Preſſure of Water upon Bodies at different Depths, and the Preſſure, Reſiſtance, and Condenſation of Air, are ſo neceſſary to be conſider'd in Diving; that giving an account here of different ways of performing that Operation, will illuſtrate the Rules already given in our Hydroſtaticks.

Experiment 17. *Plate* 20. *Fig.* 1.

In the large Glaſs Jar A L fill'd with Water up to S S, invert a ſmall empty Glaſs Jar B C, of about 10 Inches in Height; and the Air in the Space B C, being of the ſame Tenor as the outward Air, will keep the Water from coming up into the little Jar by its Spring againſt the Preſſure of the outward Air that would drive it in. But as from the Surface of the Water in the great Jar at S S, to the Mouth of the little Jar at C, there is an Height of Water B C of 10 Inches, (the 38th Part of 32 Foot, the Height of Water, whoſe Preſſure is equal to the Weight of the Atmoſphere) the Air in the little Jar is $\frac{1}{38}$ more preſs'd than it would be by the Atmoſphere, or outward Air alone, and therefore muſt recede accordingly, and conſequently give way to the Riſe of a ſmall Height of Water, which juſt ſhews itſelf within the little Jar at its Mouth C. If the little Jar B C was plung'd under Water, till its Mouth C was 32 Foot below the Surface, the Height of Water B C would become ſuch

Plate. 20. Fig. 1.

as

Lect. IX. Plate 20. Fig. 1, 2.

as would preſs equally with, and muſt be added to the Preſſure of the Atmoſphere, or outward Air; and then the Spring of the Air included in B C, having cut half the Force of this increas'd Preſſure, would yield and recede to D, where by its doubled Denſity it would become able to ſuſtain this double Preſſure. The Water therefore following would riſe into the Jar, (always ſuppoſing it cylindrick) one half of its Height, or C D. If B C was plung'd 64 Foot under the Surface of the Water, the Water would riſe $\frac{2}{3}$ in this Jar towards B; if 96 Feet, $\frac{3}{4}$, *&c.* And if we call'd every Depth of 32 Feet of Water one Atmoſphere, (becauſe that Height preſſes as much as the Atmoſphere, or outward Air)——In theſe Fractions $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$, $\frac{5}{6}$, *&c.* the Numerators will expreſs the additional Atmoſpheres that preſs up the Water at the ſeveral Depths, and the Denominators the Degree of Denſity to which the Air is compreſs'd.

Experiment 18. *Plate* 20. *Fig.* 1.

The Tube G T is 32 Inches long: when its open End T (the other being ſhut) is juſt put down to the Surface of the Water S S, no Water is viſible in it; but as ſoon as you have plung'd that open End one Foot under the Water's Surface, the Water will riſe up into the Tube the Height T *t*, or one Inch, the Air yielding $\frac{1}{32}$ Part; becauſe the Preſſure of the Height of Water S L is added to the Preſſure of the Atmoſphere upon the Surface of the Water S S.

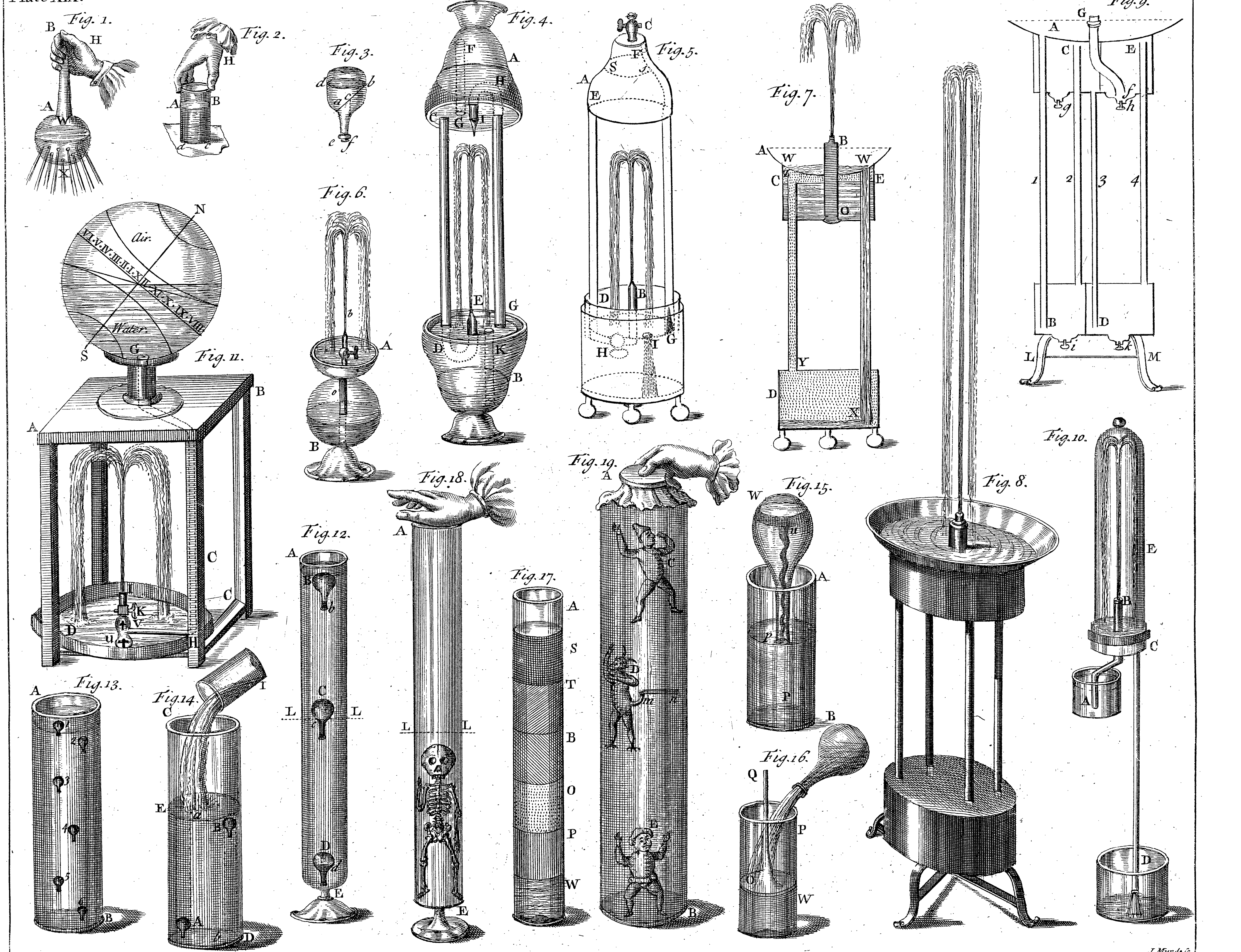
N. B. *Tho' we have taken* 32 *Feet in Height to repreſent the Height of Water equal to the Preſſure of the Atmoſphere, any Number of Feet would do from* 32 *to* 35, *becauſe the Preſſure of the Air varies in that Proportion according to the Seaſons.*

Experiment 19. *Plate* 20. *Fig.* 2.

E C D is a little Bell of Glaſs hanging by the String R E into the Jar of Water A B. A Circle of Lead C D, being ſlipp'd on upon it, and having a great many Leaden Bullets hanging from it to increaſe its Weight, makes the Bell ſink down under Water, which, without that, would float by reaſon of the Air contain'd in it: and now the Water does not go into it, but only ſhew itſelf at its Mouth. For in taking the Bell out of the Jar, you may find that a Paper P, which had been ſtuck in its upper Part within, comes out without being wet. An Inſtrument of this Figure, but big enough to contain one or two Men ſtanding upon Ledges fix'd to its Bottom, made of Wood, and cover'd with Lead, and made ſtill heavier with Cannon Ball hanging round it, is the common *Campana urinatoria*, or Diver's Bell made uſe of to go down to the Bottom of Rivers,

Plate XIX.

front.^o pa. 212.



Rivers, or of the Sea, where it is not very deep. It is made of this Figure rather than that of a Cylinder; because at the same Depth the Water will not rise so high in the Bell as it would in a Cylinder, and a Man may descend lower than in a Cylinder before the Water is troublesome to him, by rising up to his Face. For example, before the Water can come up to S S, half the Height of the Bell, the Bell must be let down to 96 Feet under the Surface of the Water; because the Space S S D C in the lower Part of the Bell, which is three Quarters of its Contents, cannot be fill'd till the Bell is let down that full Depth: so that a Man may have his Head still above Water, when the Bell is let down very low. Lect. IX. Plate. 20. Fig. 2, 3.

These Bells were formerly used, but were left off on account of the following Inconveniencies.

1. A Man that is let down to any considerable Depth under Water, when the Bell rests on, or is very near the Bottom, cannot well work at Bottom, without plunging his Head under Water, or using very unmanageable Tools.

2. As we cannot long breathe the same Air before it becomes suffocating, (a Gallon of Air serving one Man but one Minute) a Man cannot remain long at the Bottom of the Water. If there was the Space of about one Hogshead for Air in the Bell when it is at Bottom, a Man could breathe that Air but one Hour; but if by the rise of the Water in the Bell that Space should be reduc'd to $\frac{1}{2}$ a Hogshead, or $\frac{1}{4}$ of a Hogshead, a Man would breathe safely but half an Hour, or a quarter of an Hour, the Lungs dilating as much at every Inspiration in condens'd, as in common Air.

3. When the Bell is let down very near the Ground, or the Mud be stirr'd up when the Bell is not quite down, it is so dark that the Men cannot well see to work.

For this reason other Inventions have been contriv'd for diving. One is a sort of a Case of Armour of Copper represented at *Figure* 3, to preserve the Diver's Body against the Pressure of the Water. This Case consists of two Pieces to be join'd together on the Body. A G B E is the Piece for the Head, and upper Part of the Body. The Head has two Copper Pipes P P, to which are to be screw'd several Lengths of Leathern Pipes to reach up to the Top, and communicate with the Air at top of the Water. These Pipes are kept open by small Hoops of Brass or Copper within the Leather. There is a convex Glass G before the Face to look thro' to see Objects under Water. The Piece E slides out, and then the Diver having put in his left Arm, and thro' the Hole opposite to B gets in his Body, and raises up his right Arm from E to B, and put it thro' the

Hole

Lect. IX. Plate 20. Fig. 3, 4.

Hole B, then the Piece E is slid up and made Water-tight, and held in place by a strong Ring at E. The Breeches or lower Piece F being put on, besides the Rings at E, is made fast to the upper Piece by two Bars with Screws C *c*, D *d*. The Arms and Hands, as well as the Thighs, and Legs and Feet being cover'd with leathern Hose, these Leathers are fasten'd to the Rings at B, and on the other Side, as also to the Breeches at F. The Air-Pipes being fasten'd at P P, the Diver is let down into the Water where he works at the Bottom, and has a small Line to pull and make Signals when he would be drawn up again; or when he would have the Boat above him move in any Direction. See the Diver with his Tools *Fig.* 4. and the Air-Pipes going up at P; together with his Line for Signals.

This kind of diving Machine has its Inconveniences.

1. When the Diver goes down to only a moderate Depth, the lateral Pressure of the Water squeezes the Air-Pipes so strongly, that the Assistants above are obliged to blow down Air to the Diver with Bellows. But the greatest Inconveniency is,

2. That when the Depth is considerable, the Diver, tho' his Breast and the rest of his Body be guarded against the Pressure of the Water, feels all the additional Weight upon his Arms and Thighs, especially where his Leathern Hose are fasten'd to the Armour, so as sometimes to stop the Circulation of the Blood, as some have experienced it to their Cost. For the external Air which comes down to them from above being taken into the Diver's Lungs, has only a Spring sufficient to bear the Pressure of the common Atmosphere, and about $\frac{1}{8}$ more upon Occasion as it is expanded about $\frac{1}{8}$ by the Heat of the human Body: whereas the Arms and Thighs defended only by oil'd Leather, must bear all the Pressure of the Water according to its Depth, besides what they used to bear above ground. The Uniformity of the Pressure does indeed help a little, and these Machines are much used, because the Places were Ships are usually cast away are but shallow. About 16 Years ago I was inform'd that there had been granted about 14 Patents for making these kind of diving Instruments, several different Persons having obtain'd those Privileges, because in their Improvements, which they call'd new Inventions, they varied a little from those that had gone before them. For great Depths, in which sometimes Ships have been cast away, or to which they have sometimes slipp'd by length of Time, where the Shore has been steep, or in Pearl and Coral-fishing, these Armour-Machines are quite useless, the Diver having bled at the Nose, Mouth and Eyes, and died soon after the Trial.

Plate 20. Fig. 5, 6, 7.

ABOUT 15 or 18 Years ago, Captain *Rowe* having obtain'd leave to work upon some Wrecks on the Coast of *Scotland*, contrived a better way than the last mention'd for diving. His Machine was such as is represented in *Fig.* 5. It is a Tub or truncated Cone made in the shape of a *Scotch* Snuff-Mill, in which the Diver is shut up by a Cover A A, fortified with Hoops, as is also the Body of the Machine at H H and *h h*. The Arms are put thro' the Holes B B and made tight, either with or without Leather Hose upon the Hands and Arms. The Legs are within the Machine turn'd back as when a Man kneels. G is a Glass to see thro', from which the Diver can wipe the Dew or Steam with his Nose upon occasion, for his Posture is to be let down with his Face downwards. The Air is shut up with him in his Tub, and is about a Hogshead in Contents; because I hear a Man shut up in it can remain in the Water about an Hour. *Fig.* 6. shews this Machine let down from a Ship with the two Ropes C *c*, D *d*; where the Diver's Arms B *b* are seen employ'd about his Work. A H *h* represents the Hoops, and L *l* the signal Line. Now, tho' this Diving-Engine be better than a great many, yet it has the same Inconveniency of not being fit for great Depths. Captain *Irwin*, who dived for Mr. *Rowe*, inform'd me that at the Depth of 11 Fathom he felt a strong Stricture about his Arms by the Pressure of the Water; and that venturing two Fathom lower to take up a lump of Earth with Pieces of Eight sticking together; the Circulation of his Blood was so far stopp'd, and he suffer'd so much, that he was forced to keep his Bed six Weeks. And I have heard of another that died in three Days, for having ventured to go down 14 Fathom.

OUR late famous Professor Dr. *Edmund Halley* improved the old Diver's Bell, so much as to have perfected the Art of living under Water, as he has given us an Account of it himself; for whoever will be at the Trouble and Expence to have a Bell made with his Improvements, may send his Divers down to any Depth with Safety. The Doctor went down himself.

Here follows a short Description of his Alterations from the common Bell.

THE 7th Figure represents Dr. *Halley*'s Bell, with the following Advantages:

1. THE Persons in the Bell sitting upon a Bench near the Bottom, could always sit dry; because whatever Depth the Bell was let down to, the Water never rose in it but to a small Height: for an Hogshead C with the Bottom out, being let down by the Side of the Bell just below its Bottom, a Man at H took hold of an Hose of Leather which com-

ing

Lect. IX. ing from the Top of the Hogſhead, hung down below it; but when it was rais'd up above the Hogſhead, the Air of the Hogſhead came up thro' it into the Bell, and puſh'd down the Water which was come up a little Height into the Bell, as R S. For the Air receiving an additional Quantity, receiv'd an additional Spring, whereby it drove out again the Water which had been puſh'd up into the Bell by the Height of the Columns of Water above its Mouth. Therefore, as the Water continually was coming up into the Bell as it was lower'd down; that Water was continually driven out again by the Air taken into the Bell every time that the Hogſhead was let down, which was very faſt; becauſe juſt raiſing it up above the Surface of the Sea, emptied its receiv'd Water, and fill'd it again with Air.

Plate 20. Fig. 7.

2. A STRONG Meniſcus Glaſs at D, concave downwards, was fix'd to the Top of the Doctor's Bell, which let in Light ſo effectually, that being in the Bell he could read the ſmall Print of the Advertiſements of a Gazette. But this was in calm Weather; for when the Sea was troubled, the Rays were by the rough Surface hinder'd from coming down, and it was ſo dark, that he was forc'd to have Candles.

N. B. A Candle of ſix in the Pound conſum'd as much Air as one Man; that is, about a Gallon in a Minute.

3. THOSE in this Bell could breathe freely a whole Day; becauſe as the Air grew effœte, and unfit for Reſpiration, the Doctor by a Cock within the Bell at B could let out the foul Air, (for the foul Air being hot, always aſcended to the Top of the Bell) and ſee by the Aſcent of the Water at the Bottom of the Bell how much foul Air had been let out, to re-ſupply it by the deſcending Hogſhead C. By this means the Bell was always full of Air, and of freſh Air.

IF any Body ſhould aſk why the Water did not come down into the Bell, when the Cock was open to let out the foul Air; let them obſerve that the Column of Water puſhing down to come in at the Mouth of the Cock B is to be meaſur'd only according to its Height reaching from the Surface of the Sea to B; but the Column of Water driving out the Air muſt be meaſur'd from the Surface of the Sea to the Bottom of the Bell at R, which is about eight Feet (or the Height of the Bell) taller. This is the Reaſon why the Glaſs D is made concave, with its Convexity downwards, that it may reſiſt the Preſſure of the Air acting upwards by the Preſſure of the Column of Water reaching down to R, when its upper Side is preſs'd only by a Column of Water reaching to D, about eight Feet ſhorter.

4. ANOTHER Improvement of the Doctor's, was, that he could ſend Men out of the Bell to work at the Diſtance of 50 or 100 Yards from

from the Bell; becauſe it would have been very troubleſome to remove the Bell over every Part of a Wreck, or of the Goods to be taken up, perhaps diſpers'd at conſiderable Diſtances from each other. To effect this, with great Difficulty he made a long ſmall Pipe of about $\frac{1}{4}$ of an Inch Bore, kept open againſt the Preſſure of the Sea by a ſmall ſpiral Wire, and made tight without by Leather painted, and Sheep's Guts drawn over it. One End of this Pipe being open, was faſten'd, or held in the Bell to receive Air at P, and the Pipe itſelf being coil'd round the Arm of the Man out of the Bell, the other End was faſten'd to a leaden Cap (call'd a Cap of Maintenance) on the Man's Head, which reach'd down below his Shoulders, open at bottom to ſerve him as a little Bell full of Air for him to breathe at his Work, which would keep out the Water from him, when at the Level of the great Bell, becauſe of the ſame Denſity as the Air in the great Bell. But when he ſtoops down lower than the Level of the great Bell, he ſhuts the Cock F, to cut off the Communication from the great Bell to his little Bell. This little Bell will ſerve him a Minute or two, till its Air grows foul; but he can inſtantly change it by raiſing himſelf above the great Bell, and opening the Cock F: for then a Puff of freſh Air coming from the great Bell, renews all his Air, by driving out the foul Air, of which his Bell was full. Then he muſt ſhut the Cock again, leſt he ſhould take too much Air from the great Bell. This travelling Diver was forc'd to have almoſt half an Hundred Weight of Lead at his Feet, to keep himſelf firm on the Ground: and whereas he could not bear the Cold, the Doctor cloath'd him in thick Flannels cloſe to all his Limbs, and made him wet them, and ſtay in the Bell till he was very warm; and thus the warm Water ſticking in his Clothes, kept out the cold Water for a long time, when he was out of the Bell.

Lect. IX.

Plate 20. Fig. 7.

By means of the Bell thus improv'd a Diver may be let down to any Depth without the leaſt Inconveniency, provided the Bell be not let down, or taken up too faſt. Becauſe the lower the Bell goes, and the more the Air is condens'd about the Divers, the greater Preſſure are they enabled to ſuſtain; for as they breathe the ſame condens'd Air, and the Air circulates with the Blood, all the Parts of their Bodies, the very Extremities of their Fingers and Toes, are arm'd againſt that Preſſure: and whether a Man be in or out of the Bell, he ſuffers the ſame Preſſure, whether from the Water, (when out of the Bell) or from the Air condens'd by it in the Bell. Care muſt be taken not to take up the Bell too faſt, becauſe the condens'd Air in the Bodies of the Divers muſt expand itſelf by degrees, and be breath'd out; otherwiſe, if they were too ſuddenly deliver'd of the outward additional Preſſure, the Air within them

would

Lect. IX. would burst them outwards. When foul Air has been let out thro' the Cock B, the Surface of the Sea has been cover'd with Foam for 40 Yards, so great has been the expansive Force of the Air; Bubbles of the Bigness of a grey Pea when they came out thro' the Cock being as big as an Orange at top of the Water. When the Pressure of the Air is the least, a Man of a middle Size sustains the Weight of 30,000 Pounds, and every five Fathoms of Sea-Water adds a Weight of 30,000 more; but the Air of the Bell gradually condens'd, and breath'd by the Divers, always enables them to bear it; and those that dive with Armour will not bear the Pressure of an Height of 60 Feet of Water, so well as a Diver in the Bell can bear the Depth of 300.

Plate 20. Fig. 8.

Dr. *Halley* told me indeed of a small Inconveniency that they had in the Bell: At first they felt a small Pain in their Ears, as if the End of a Tobacco-Pipe was thrust in their Ears; but after a little time, there was a small Puff of Air with a little Noise, and they were easy. He thought it was occasion'd by the condens'd Air shutting up a Valve leading from some Cavity in the Ear full of common Air; but when the condens'd Air press'd a little hard, it forc'd the Valve to yield, and fill'd every Cavity. One of the Men, to prevent this Pressure, stopp'd his Ear with a Pellet of chew'd Paper; but that Pellet was push'd in so far, that the Surgeon had much ado to get it out. I shall conclude this Narration, with observing that there was an easy Correspondence between those in the Bell, and in the Ship above, by writing with a Nail on a Plate of Lead tied to the descending Hogshead C, which the Man at H taking in, the Answer to the Letter from above was written on the other side of the Leaden Plate, from which the Writing was beaten out upon an Anvil, when it had been read above: then they wrote again upon one Side.

32. In *November* in the Year 1732, I receiv'd a Letter from a very ingenious Gentleman, Mr. *Martin Triewald*, F. R. S. Captain of *Mechanics*, and *Military Architect* to his *Swedish* Majesty, concerning the Improvement of Dr. *Halley*'s *Diving Bell*, which he has made cheap, and entirely perfected; and therefore deserves my Reader's Perusal. See *Plate* 20. *Fig.* 8.

Stockholm, *Nov.* 1. 1732.

Reverend Sir,

" Having the sole Privilege for diving on all the Coasts in the *Baltic*
" belonging to his *Swedish* Majesty, no Opportunity has been
" wanting to make sufficient Trials with the Diving-Bell and Air-Barrels
" in

" in ſeveral Depths, according to the ingenious Improvement of that " worthy Gentleman Dr. *Edmund Halley*, made in the Year 1716, but " with ſmall Additions.——Experience has likewiſe convinc'd me, that " no Invention built upon any other Principles than thoſe of the *Campana* " *Urinatoria*, can be of uſe in any conſiderable Depths; or that the " Diver, in any other Invention whatever, can be a ſingle Moment ſafe. " I will not, for brevity ſake, mention the many Impediments that at- " tend other Inventions, only that of a Water-Armour, in which a Man " is drowned in an inſtant, when ſuch a Machine receives the leaſt Leak: " whereas Experience has ſhewn, that when ſuch an Accident has hap- " pened to the Diving-Bell, as to my knowledge it did once, when the " Diver was 12 Fathom under Water, and a pretty large Hole happen'd " to be ſtruck in the Bell, by a Bolt of the Wreck he went upon; at " which time the Air ruſh'd out of the ſame with ſuch Violence as aſto- " niſhed the Beholders, by the exceſſive boiling on the Surface of the " Water, fearing, not without reaſon, that the Man in the Bell was " drowned; but he clapped his Hand to the Hole or Leak, and gave a " Sign to be haul'd up, which was done with all the Eaſe and Safety as " if no Accident had happen'd to him, the Water having only riſen about " half a Foot into the Bell by this Leak. The very ſame Diver that was " then in the Bell is 63 Years of Age, and has uſed the Buſineſs of Div- " ing ever ſince he was 20, in a common Diving-Bell, till of late, and " is as yet a pretty ſtrong and healthy Man: He declares, that never a " worſe Accident happen'd to him in his Buſineſs but once, when the " Bell he was in ruſh'd down at once about a Fathom or more, by the " Careleſſneſs of thoſe that worked the Bell; at which time the Blood " came out of his Noſe and Ears, feeling beſides an intolerable Preſſure " on his whole Body; which ſhews, that when a Man in a Diving-Bell " is ſlowly and gradually let down, he at ſuch a time, and by degrees " reſpiring compreſs'd Air, which by the Lungs is forced into the Blood, " cannot feel the external Preſſure, tho' of highly compreſs'd Air, ſur- " rounding him, and that of the Water reaching ſome Parts of his Body; " which Convenience no other Invention can yield or afford, where the " Diver is to draw his Breath from Air in its natural State.——I have " often with a great deal of pleaſure obſerved, that when I have cauſed " the Bell to ſtop, being lower'd down five Fathom, and the Diver taking " in the Air contained in an Air-Barrel, lower'd down a Fathom deeper " than the Bell, without opening the Cock for diſcharging the hot Air; " the Water would, by the Acceſs of the Air out of the Barrel, be quite, " or to a very ſmall matter, expell'd out of the Bell; and when the ſame " was again lower'd down five Fathom more, the ſame Operation with

Lect. IX. " another Air-Barrel repeated, and the Bell afterwards haul'd up, it was " no ſmall matter of Delight to ſee, that every Fathom the Bell came " up, it would diſcharge itſelf of the ſuperfluous and large Quantity of " Air, which came from the Bottom of the Bell in very large Bubbles, as " big as Eggs of an Oſtrich; which Diſcharge of Air and Phænomenon " continued, till the *Æquilibrium* of the Air in the Bell, and Preſſure of " the Water was reſtored, and till the Bell came above the Surface of " the Water. At other times I have obſerved, when no Air was by the " way taken into the Bell, but the ſame lower'd down the common " way, and haul'd up again for ſome time, that the very Inſtant when " the Bell ſhould part with the Surface of the Water, the Strength of " two Men more was required at the Capſton at that time, than before " and after the Bell hung freely in the Air; from whence I preſume it " plainly appears, that the Air that paſſes thro' the Lungs of a living " Creature, loſes its Elaſticity, and that the Lungs of a Man make a " kind of a Vacuum in the Bell; for which reaſon the Diver feels at the " very Inſtant, when the Bell parts with the Water, a very ſmart Preſ- " ſure in his Ears.

" THO' Experience thus has taught me, that no Invention is more " ſafe and uſeful than the *Campana Urinatoria*, with the ingenious Im- " provement of Dr. *Halley*; yet I have likewiſe found, that this Inven- " tion is not to be made uſe of without conſiderable Charge, requiring a " large Veſſel, and number of Hands, to the working and managing of " ſuch a large Diving-Bell, and the Air-Barrels with their reſpective " Weights for ſinking; which Charges, however, according to the " Depth of Water, and the Value of what is to be fetch'd up from the " Bottom of the Sea, may not be regarded: but ſince it more frequently " happens in theſe Parts, that Cargoes of a far leſs Value than the Load- " ings of *Spaniſh* Galleons, &c. are to be dived for; then next to the " Goodneſs of the Invention, I have found myſelf neceſſitated to think " how the Expences might be leſſened, and that the Diving-Bell never- " theleſs might anſwer all the Intents and Purpoſes of Dr. *Halley's*; which " Improvement I take herewith the liberty to communicate to you, " which is as follows.

Plate 20. Fig. 8. " THE Diving-Bell A B, (ſee *Fig.* 8.) I have cauſed to be made " of Copper, and reduced the ſame to a very little Compaſs in regard to " that of Dr. *Halley's*, as you'll ſee by the Scale under the Draught, by " which means it is eaſily managed by two Hands: yet I preſume that a " Diver may not only live in the ſame for as long a time, and with as " much Eaſe, at a very conſiderable Depth of Water, as in a Bell of " twice its Capacity, for this reaſon; tho' a Man in a large Bell has un- " doubtedly

" doubtedly more Air than in a less, and consequently should be able to " subsist a great while longer on a large Quantity of Air, than on a small " Parcel; yet, because his Head for the most part is kept in the upper " Part of the Bell, where the hot Air takes up its Place and Residence, " he receives very little or no Benefit of the Air under his Chin or " Breast, tho' never so fit for Respiration; which Air nevertheless in the " lower Parts of the Bell will remain cool a long time after he has been " in the Bell, and with difficulty drawn his Breath; which cannot be " denied, and is very obvious to any body who has been in a *German* " Bagnio, and such as are made use of in this Country, where in a single " Room all the Degrees of Heat are to be felt, by means of a Con- " trivance like Stairs to the very top of the Cieling; a Man when he " places himself on the uppermost Step will feel an excessive Heat; so " that any body not very much used to it cannot endure the same, nor " draw his Breath, but will faint away; whereas on the first, second " or third Steps from the Floor, the Heat is very moderate; nay some- " times the Air near the Floor is pretty cool, when at the same time " near the Cieling the Heat of the same is intolerable. I will not men- " tion many other Instances, I could produce.

" To encounter this Inconvenience, I have caused a spiral Tube of " Copper, *b*, *c*, to be placed close to the Inside of the Bell, so fixed that " the same may be taken out and cleansed at Pleasure, and with Ease; " and at the same time not to incumber the Diver when he is in the " Bell; at the upper End of this Tube *b*, a flexible Leather Tube is " joined two foot long, at the end of which is a turn'd Ivory Mouth- " piece, which the Diver (as soon as he perceives the Air to grow hot " in the Top of the Bell,) keeps constantly in his Mouth, which he is " able to do by means of the flexible Tube in whatever posture he is " in, standing, sitting, bowing his Head, *&c*. And all the while he " draws his Breath thro' the afore-mentioned Tube, and the Air from " *c*; by which contrivance he not only draws continually cool and fresh " Air as long as any is in the Bell, but occasions at the same time a " Circulation, which is so necessary to the very Being of Air, (especially " in a compressed State) and its Preservation for the Use of Animals, " which I have found to be of great consequence; and so much the " more necessary, as any body who has been in a diving Bell for a long " time, without any new Supplies of Air, and has been reduced to the " last Extremity of Breathing in the same, will agree with me, that " when at such time the Bell begins to be haul'd up, and by that means " the compressed Air allowed to expand, and be put into motion never " so little, the Man receives, as it were, a new Life, and incredible

" Comfort

Lect. IX. Plate. 20. Fig. 8.

" Comfort and Ease. Again, when in Coal-pits, Levels are drove in " the Coal, or thro' Dykes, the Air of the Level, or Adits, growing hot " by the Breath and Sweat of the Hewers and Workmen for want of a " Circulation of the Air; I have found it to be an excellent Remedy, " to place along the Side of the Drift or Adit, a square Wooden Box, " open at both Ends, laid from the Place where the Air is cool and " good, reaching as far, by joining one Box close to another, as where " the Work is carried on. Thus, by this simple Contrivance, a Circu-" lation of Air is obtained, and sometimes to that degree, that when a " Candle is held at the End of the Box where the cool Air enters, the " Flame is driven out by the Current of cold Air entring and circu-" lating thro' the Box.

" By which Experiment I am apt to think, that tho' the Diver should " not keep the End of the flexible Tube in his Mouth, which he may " do with all the Ease in the world, yet that the Air would circulate " thro' the Copper Tube, and he receive no small Benefit by it. " D.D.D.D are the Weights for sinking the Bell, so contrived as with " great ease to be hooked on the same hanging on the Table. The " Iron Plate E, fixed to the Chains F F F, serves the Diver to stand " upon, when he is at work. The Bell is extremely well tinn'd with-" in all over; and as in all Rivers, and the Coasts of the *Baltic Sea*, " the Water is extremely clear and bright, because of no Ebb and Flood, " I have placed three strong convex Lenses G G G. By these means " the Diver can not only see what is under him, but likewise on all " Sides at a good distance.

" These Glasses have strong Copper-lids like Snuff-boxes, H H H; " which Lids are shut, when there is no occasion to discover any Objects " on the bottom of the Sea, and serve to preserve the Glasses from being " broken.

" I Hope you'll pardon the Liberty I have taken, to trouble you " with a long Letter, which I might have enlarged with an Account " of other Inventions, which, if you approve of this, shall in a little time " follow: In the Interim I beg you'll grant me leave to remain with " much Respect

" *Reverend SIR,*

" *Your most obedient and devoted humble Servant,*

M. TRIEWALD,
F.R.S. *Berl.* and *Swed.*

33. The

33. The Compression of Air by different Depths of Water is measur'd, and consequently any Depth of the Sea, by a Machine contrived by Dr. *Stephen Hales* and my self, which I shewed the Royal Society in *November* 1728; and of which here follows the Account that I then gave in. There have been several Machines contrived for measuring the different Depths of the Sea, especially such as could not be determined by the Lead and Line; but as those Machines consisted of two Bodies (the one specifically lighter and the other specifically heavier than Water) so joined together, that as soon as the heavy one came to the bottom, the lighter should get loose from it, and emerge; and the Depth was to be estimated by the Time of the Fall of the compound Body from the top to the bottom of the Water, together with the Time of the Emersion of the lighter Body, reckon'd from the disappearing of the Machine, till the emergent Body was seen again, no certain Consequence could be drawn from so precarious and incomplete an Experiment.

For even in still Water, and in the same Place, the Time will hardly be the same in two Experiments: much less will this Machine answer in the Sea, on account of the Waves and Currents, and many other Hindrances.

But as the Pressure of Fluids in all Directions is always the same at the same Depth, a Gage which discovers what the Pressure is at the Bottom of the Sea, will shew what the true Depth of the Sea is in that Place, whether the Time of the Descent of the Machine be but a Minute or two, or twenty times as long.

The Reverend Dr. *Hales*, in his *Vegetable Staticks*, describes his Gage for estimating the Pressures made in opaque Vessels; where Honey being pour'd over the Surface of Mercury in an open Vessel, rises upon the Surface of the Mercury as it is pressed up into a Tube whose lower Orifice is immers'd into the Honey and Mercury, and whose top is hermetically sealed. Now as by the Pressure, the Air in the Tube is condens'd, and the Mercury rises, so the Mercury comes down again when the Pressure is taken off, and would leave no Mark of the Height to which it had risen; but the Honey (or Treacle, which does better) which is upon the Mercury, sticking to the Inside of the Tube, leaves a Mark, which shews the Height to which the Mercury had risen, and consequently makes appear what was the greatest Pressure.

My Contrivance therefore is a Machine which will carry down Dr. *Hales*'s Gage to the bottom of the Sea, and immediately bring it up again. See *Fig.* 9. AB the Gage-Bottle, F*f* the Gage-Tube cemented to the Brass Cap of the Bottle at G, with its open End *f* immersed in the Plate 20. Fig. 9.

Lect. IX. Plate 20. Fig. 9. the Mercury C, which by the Preſſure of thirty-two Foot of Water is carried up to *d* with a little Treacle or Honey *d* upon it, raiſed up from D, a ſmall Thickneſs of Treacle pour'd on upon the Mercury.

When the Preſſure of Water is from a Depth of 64 Foot, the Mercury and Treacle riſe up to E, $\frac{2}{3}$ of the Height of the Tube; and ſo higher proportionably to the Depth.

N. B. *A Scale may be marked on the Tube with a Diamond.*

K is a Weight hanging by its Shank L in a Socket *l*, fixed at the Ring M B cemented at the Bottom of the Bottle. When the Hole L of the Shank is ſhov'd up to *m*, the Catch *l* of the Spring S holds it from falling out of the Socket, whilſt the Machine is deſcending. But as ſoon as K touches the Ground at the Bottom of the Sea, the Hole L riſing, the Catch flies back and lets go the Weight, as it is ſeen in the Figure. Then the empty Glaſs Ball I, (which at Sea may be a Hog's Bladder) riſes up to the Surface of the Water with the Machine, in which obſerving how high the Inſide of the Tube is daub'd, the Preſſure, and conſequently the Depth of the Sea is known.

H G, is a Braſs Tube to guard the Top of the Gage-Tube.

There are Holes at F, G, and E, to admit the Water to paſs freely every where.

To confirm the Uſe of this Sea-Gage, ſhewn before the Society, I made another Experiment in the following manner. Having pour'd ſome Quickſilver into the Bottle of the Gage, I pour'd on upon it Treacle to the Depth of half an Inch, then ſcrewed on the Braſs Cap of the Bottle to which the Glaſs Gage-Tube was cemented; by which means the open End of the Tube was brought under the Surface of the Mercury, the ſealed End being upwards. The Machine thus fitted, was immerſed in a Cylindric Veſſel of Water, which with the Plate at top was preſſed between two Pillars, in ſuch manner that Air might be condenſed over the Water without eſcaping. Then having forced in ſo much Air with a Syringe as to lay on a Preſſure equal to what would be in a Depth of 40 Foot of Water, I open the Cock of the upper Plate, let out the Air, and, upon taking out the Machine, it appeared how high the Quickſilver had riſen in the Gage-Tube, by the greaſy Mark which the Treacle left within.

Dr. *Hales* has ſince made more Experiments of this ſort, and propos'd another Sea-Gage for vaſt Depths; of which we ſhall give an account in the Notes *.

* Annot. 9.

Of the RESISTANCE *of Fluids.*

ALL the Bodies mov'd in Fluids suffer Resistance, which arises from two Causes. The first is the Cohesion of the Parts of the Liquid. A Body in its Motion, separating the Parts of a Liquid, must overcome the Force with which those Parts cohere, and thereby its Motion is retarded. The second is the *Inertia*, or Inactivity of Matter, that belongs to all Bodies, which is the reason, that a certain Force is required to remove the Particles from their Places, in order to let the Body pass. The Body acts upon the Parts to remove them, and they diminish its Motion by Re-action.

THE Retardation from the first Cause, that is, the Cohesion of Parts, is always the same in the same Space, the same Body remaining, be the Velocity of the Body what it will. The same Cohesion is to be overcome in every case; therefore this Resistance increases at the Space run through, in which Ratio the Velocity also increases; therefore it is as the Velocity itself.

THE Resistance arising from the *Inertia*, or Inactivity of Matter, when the same Body moves thro' different Liquids with the same Velocities, follows the Proportion of the Matter to be removed in the same Time, which is as the Density of the Liquid.

WHEN the same Body moves thro' the same Liquid with different Velocities, this Resistance increases in proportion to the Number of Particles struck in an equal Time, which Number is as the Space run thro' in that Time, that is, as the Velocity. But this Resistance does farther increase in proportion to the Force with which the Body runs against every Part; which Force is also as the Velocity of the Body. And therefore if the Velocity is triple, the Resistance is triple from a triple Number of Parts to be remov'd out of their Places. It is also triple from a Blow three times stronger against every Particle; therefore the whole Resistance is ninefold, that is, as the Square of the Velocity.

A BODY therefore mov'd in a Liquid is resisted partly in a Ratio of the Velocity, and partly in a duplicate Ratio of it. The Resistance from the Cohesion of Parts in Liquids, except glutinous ones, is not very sensible in respect of the other Resistance: which as it increases in a Ratio of the Squares of the Velocities, but the first in a Ratio of the Velocity itself; by how much the Velocity increases, by so much more do these Resistances differ amongst themselves: wherefore, in swifter Motions the Resistance alone is to be considered, which is as the Square of the Velocity.

Lect. IX. I SHALL not now treat of tenacious or glutinous Liquids, nor of ſlow Motions, in which the Reſiſtance ariſing from the Coheſion of the Parts muſt be conſider'd.

IF a Liquid be included in a Veſſel of a priſmatical Figure, and there be moved along in it with equal Velocity, and a Direction parallel to the Sides of the Priſm, two Bodies, the one ſpherical, and the other cylindric, ſo that the Diameter of the Baſe of this laſt be equal to the Diameter of the Sphere, and the Cylinder be mov'd in the Direction of its Axis, theſe Bodies will ſuffer the ſame Reſiſtance. To demonſtrate this, ſuppoſe the Bodies at reſt, and that the Liquid moves in the Veſſel with the ſame Velocity that the Bodies had; by this the relative Motion of the Bodies and the Liquid is not changed, therefore the Actions of the Bodies on the Liquid, and of the Liquid on the Bodies, are not changed. The Retardation which the Liquor ſuffers in paſſing by the Body, ariſes only from this, That in that Place it is reduced to a narrower Space, but the Capacity of the Veſſel is equally diminiſhed by each Body; therefore each Body produces an equal Retardation. And becauſe Action and Reaction are equal to one another, the Liquids act equally upon each Body; wherefore alſo each Body is equally retarded, when the Bodies are moved, and the Liquid is at reſt.

THIS Demonſtration will alſo obtain, tho' the Veſſel be ſuppos'd much bigger; and it will do in an infinite Liquid compreſs'd; therefore it may be referr'd to Bodies deeply immers'd. Here we ſpeak of a continuous Liquid, and whoſe Parts cannot be reduced into a leſs Space by Preſſure; otherwiſe there will be an Accumulation before the Body, and a Relaxation behind; and ſo much the more, the more blunt the Body is; which alſo cauſes a greater Irregularity in the Motion of the Liquid, and a greater Retardation in the Motion of the Body.

WHEN a Body is mov'd in any Liquid along the Surface, the Liquid is rais'd before the Body, and depreſs'd behind; and theſe Elevations and Depreſſions are greater, the more blunt the Body is, and by that means it is more retarded; for there is alſo a greater Irregularity in the Motion of the Liquid in this caſe, which ſtill more increaſes the Retardation of the Body. This is alſo true, if the Body be not immerſed deep; yet in that caſe the Irregularity of the Motion of the Liquid is the chief Cauſe of the Retardation.

THEREFORE, to take away theſe Irregularities, we muſt conſider Bodies as deeply immers'd, and give Rules relating to them; by which the Retardations in ſeveral caſes may be compar'd together. We ſuppoſe the Bodies ſpherical, tho' the Demonſtrations will ſerve for all ſimilar Bodies mov'd in the ſame manner.

HERE

HERE you must observe, that the Resistance is to be distinguish'd from the Retardation; the Resistance produces the Retardation. When we speak of the same Body, the one may be taken for the other, because they are in the same Proportion; but, supposing the Bodies different, the same Resistance often generates different Retardations. From the different Resistance arises a Motion contrary to the Motion of the Body; the Retardation is the Celerity, and the Resistance itself is the Quantity of Motion.

LET the Bodies be equal, but of different Densities, and mov'd thro' the same Liquid with equal Velocity, the Liquid acts in the same manner upon both; therefore they suffer the same Resistance, but different Retardations; and they are to one another as the Celerities, which may be generated by the same Forces in the Bodies propos'd; that is, they are inversly as the Quantities of Matter in those Bodies, or inversly as the Densities.

NOW, supposing Bodies of the same Density, but unequal, mov'd equally fast thro' the same Fluid, the Resistances increase according to their Superficies, that is, as the Squares of their Diameters; the Quantities are increas'd in proportion to the Cubes of the Diameter, the Resistances are the Quantities of Motion, the Retardations are the Celerities arising from them, dividing the Quantities of Motion by the Quantities of Matter, you will have the Celerities; therefore the Retardations are directly as the Squares of the Diameters, and inversly as the Cubes of the Diameters; that is, inversly, as the Diameters themselves.

IF the Bodies are equal, move equally swift, and are of the same Density, but are mov'd thro' different Liquids, their Retardations are as the Densities of those Liquids.

WHEN Bodies, equally dense and equal, are carried thro' the same Liquid with different Velocities, the Retardations are as the Squares of the Velocities.

FROM what has been said, the Retardations of any Motions may be compar'd together, for they are first, as the Squares of the Velocities; secondly, as the Densities of the Liquids, thro' which the Bodies are mov'd; thirdly, inversly, as the Diameters of those Bodies; lastly, inversly, as the Densities of the Bodies themselves.

THE Numbers in the Ratio, compounded of those Ratio's, express the Proportion of the Retardations, multiplying the Square of the Velocity by the Density of the Liquid, and dividing the Product by the Product of the Diameter of the Body multiplied into its Density, and working thus for several Motions, the Quotients of the Divisions will still have the same compound Ratio to one another.

Lect. IX. THESE Retardations may be alſo compar'd together, by comparing the Reſiſtance with the Gravity. It is demonſtrated, that the Reſiſtance of a Cylinder, which moves in the Direction of its Axis (to which the Reſiſtance of a Sphere of the ſame Diameter is equal) is equal to the Weight of a Cylinder made of that Liquid, thro' which the Body is mov'd, having its Baſe equal to the Body's Baſe, and its Height equal to half the Height, from which a Body falling *in vacuo* may acquire the Velocity with which the ſaid Cylinder is mov'd thro' the Liquid. From the given Celerity of the Body mov'd, the Height of the Liquid Cylinder is found, as alſo the Weight of it from the known ſpecifick Gravity of the Liquid and Diameter of the Body. Let a Ball, for Example, of 3 Inches Diameter be mov'd in Water with that Celerity with which it wou'd go thro' 16 Foot in a Second: From what has been ſaid of falling Bodies and Pendulums, as alſo by Experiments made on Pendulums, it has been found that this is the Celerity which a Body acquires in falling from a Height of 4 Foot; therefore the Weight of a Cylinder of Water, of 3 Inches Diameter, and two Foot high, that is, a Weight of about 6 Pounds, is equal to the Reſiſtance of the aforeſaid Ball.

LET the Reſiſtance ſo diſcover'd be divided by the Weight of the Body, which determines its Quantity of Matter, and you will have the Retardation. By which Rule the Proportion of the ſeveral Retardations is diſcover'd, and found to be the ſame as is given by the foregoing Rule.

A BODY freely deſcending in a Liquid is accelerated by the reſpective Gravity of the Body which continually acts upon it; yet not equally, as in a Vacuum, the Reſiſtance of the Liquid occaſions a Retardation, that is a Diminution of Acceleration, which Diminution increaſes with the Velocity of the Body. For there is a certain Velocity which is the greateſt that a Body can acquire by falling; for if its Velocity be ſuch, that the Reſiſtance ariſing from it becomes equal to the reſpective Weight of the Body, its Motion can be no longer accelerated; for the Motion which is continually generated by the reſpective Gravity, will be deſtroy'd by the Reſiſtance, and the Body forc'd to go on equably: the Body continually comes nearer and nearer to this greateſt Celerity, but can never attain to it.

WHEN the Denſities of a Liquid and a Body are given, you have the reſpective Weight of the Body; and by knowing the Diameter of the Body, you may find out from what Height a Body falling *in vacuo* can acquire ſuch a Velocity, that the Reſiſtance in a Liquid ſhall be equal to that reſpective Weight, which will be the greateſt Velocity abovemention'd.

If the Body be a Sphere, it is known that a Sphere is equal to a Cylinder of the same Diameter, whose Height is two third Parts of that Diameter; which Height is to be increas'd in the Ratio in which the respective Weight of the Body exceeds the Weight of the Liquid, in order to have the Height of the Cylinder of the Liquid, whose Weight is equal to the respective Weight of the Body: but, if you double this Height, you will have a Height, from which a Body, falling *in vacuo*, acquires such a Velocity as generates a Resistance equal to this respective Weight, and which therefore is the greatest Velocity which a Body can acquire, falling in a Liquid from an infinite Height.

Lead is eleven times heavier than Water, wherefore its respective Weight is to the Weight of Water as 10 to 1; therefore a Leaden Ball, as it appears from what has been said, cannot acquire a greater Velocity, falling in Water, than it would acquire in falling *in vacuo*, from an Height of $13\frac{1}{3}$ of its Diameter.

A Body lighter than a Liquid, and ascending in it by the Action of the Liquid, is moved exactly by the same Laws as a heavier Body falling in the Liquid. Where-ever you place the Body, it is sustained by the Liquid, and carried up with a Force equal to the Difference of the Weight of the Quantity of the Liquid, of the same Bulk as the Body, from the Weight of the Body, therefore you have the Force that continually acts equably upon the Body, by which, not only the Action of the Gravity of the Body is destroy'd, so that it is not to be considered in this case, but by which also the Body is carried upwards by a Motion equably accelerated, in the same manner as a Body heavier than a Liquid, descends by its respective Gravity; but the Equability of the Acceleration is destroy'd in the same manner by the Resistance, in the Ascent of a Body lighter than the Liquid, as it is destroy'd in the Descent of a Body heavier than the Liquid.

When a Body specifically heavier than a Liquid, is thrown up in it, it is retarded upon a double account; on account of the Gravity of the Body, and on account of the Resistance of the Liquid; therefore a Body rises to a less Height than it would rise *in vacuo* with the same Celerity. But the Defects of the Height in a Liquid, from the Heights to which a Body would rise *in vacuo* with the same Celerities, have greater Proportion to each other than the Heights themselves; and, in less Heights, the Defects are nearly as the Squares of the Heights *in vacuo*.

In the Annotations to our seventh Lecture, we have explain'd the Conduct and Expence of Water from Ponds and Reservoirs sufficient for Practice; now we will be yet more exact upon that Subject, giving the Considerations.

Lect. IX. *Considerations and Experiments from which a great many of the practical Rules were at first deduc'd.*

We shall here take particular Notice of what happens to Liquids flowing out of Vessels, and the Irregularities of that Motion.

THE Quantity of a Liquid, which in a given Time flows from a given Hole, increases in Proportion to the Velocity of the Liquid going out; this depends upon the Height of the Liquid above the Hole, and it is no matter to what part the Motion of the Liquid is directed; therefore the Squares of the Quantities flowing out, are in the Ratio of the Heights of the Liquid above the Holes.

IN Vessels which are not supplied by the flowing in of the Liquid, the Celerity of the Liquid flowing out is continually chang'd; to which Regard must be had, when you compare together the Times in which different Vessels are emptied.

HERE we consider cylindric Vessels; and what is here said may be applied to any Vessels that are of the same bigness from top to bottom; we suppose the Liquid to flow out from a Hole in the Bottom.

THE Times in which cylindric Vessels of the same Diameter and Height are emptied, the Liquid flowing from unequal Holes, are to each other inversly as those Holes.

WHEN the Vessels are cylindric, unequal, and equally high, they are emptied thro' equal Holes, in Times that are to one another as the Bases of the Cylinders.

LASTLY, Let there be two cylindric Vessels, whose Bases are equal, but their Heights, for Example, as 1 to 4, and let them be evacuated thro' equal Holes. The Times in which correspondent Parts are emptied are as 1 to 2; because in twice the Time with a double Celerity, a quadruple Quantity is emptied. But as the Times are in the same Ratio for each correspondent Part, the Times in which the whole Vessels are emptied are also, as 1 to 2. If the Vessels are as 1 to 9, the Times will be, as 1 to 3; As the Heights of the Vessels, so are the Squares of the Times.

EXPERIMENT 20. *Plate* 20. *Fig.* 10.

Plate 20. Fig. 10.

LET there be three thin cylindric Vessels of Metal A, C, B, having equal Diameters, and whose Heights are, as 1, 3, and 4; let each of them have a Lip in the top, to let the Water run out when it comes to a certain Height, which Lip must be reckon'd the Top of the Vessel; in the Bottoms of the Vessels A and B, which are as 1 to 4, let there be equal Holes, and let them be filled with Water; let the Holes be open'd in the same Moment; if the Water running out of B be receiv'd in the Vessel C, it will be fill'd in the same time that A is evacuated. C contains

contains three Quarters of the Veſſel B; the Quarter which is left will also be evacuated in the ſame time as the Veſſel A, which is evident to Senſe; therefore A is emptied twice, whilſt B is emptied once. Lect. IX. Plate 20. Fig. 10.

The Times in which any cylindric Veſſels are evacuated, are in a Ratio compounded of the Baſes, of the inverſe Ratio of the Holes, and of the ſquare Roots of the Heights.

The cylindric Veſſel may be ſo divided, that the Parts intercepted between the Diviſions ſhall be emptied in equal Times, which will happen, if the Diſtances of the Diviſions from the Baſe be as the Squares of the natural Numbers; for the Times of the Evacuations of the Veſſels, whoſe Heights are in that Proportion, are as the natural Numbers, and the Differences of the Times are equal.

The Time in which a cylindric Veſſel is emptied, is as the Celerity with which the Liquid begins to run out; therefore the Celerity, while the Liquid deſcends in the Veſſel, is diminiſhed in the ſame Ratio as the Time of the Evacuation of the Liquid remaining in the Veſſel, and the Motion of a Liquid running out of a cylindric Veſſel, is equally retarded in equal Times.

If thro' equal Holes a Liquid runs out of a Cylinder, and out of another Veſſel of the ſame Height, (and in which the Liquid is always ſupplied, ſo as to be kept at the ſame Height) in the Time in which the Cylinder is emptied, there runs out twice as much Water from the other Veſſel as from the Cylinder.

Besides the Irregularities from Friction, and the Reſiſtance of the Air, there are ſeveral others ariſing from the Coheſion of Parts, even in Liquors that are not glutinous. I ſhall here only ſpeak of Water. We obſerve in relation to it, that tho' it be driven by the ſame Force in any Direction, the Height of the Water above the Hole remaining the ſame, yet it will deſcend the more ſwiftly in a vertical Direction; the Water in falling is continually accelerated in its Motion, it coheres with the following Water, and accelerates that, and increaſes the Velocity of the Water flowing out of the Veſſel.

Experiment 21. *Plate* 20. *Fig.* 10.

For this reaſon the Motion out of a Veſſel, that has a Tube fix'd to its Under-Side, is alſo accelerated. Let E be ſuch a Veſſel equal and ſimilar to the Veſſel A; and which, together with the Tube, makes up the Height of the Veſſel B; let the Tube have the Holes at both Ends, equal to the Holes at the Bottoms of the Veſſels A and B; fill the Water in the Veſſels A, E, and B. In the Beginning of the Motion, the Water flows from the Veſſel E and B with equal Celerity, becauſe the Heights of the Water above the Holes, from which the Water goes out, are equal;

Lect. IX. Plate 20. Fig. 10.

equal; but the Celerity, in the Veſſel E, is immediately diminiſh'd, becauſe there cannot run a greater Quantity of Water out of the Tube than what comes in at the upper Hole of the Tube, into which Hole no more Water can run in, than what can flow out of the Veſſel A. Since the Parts of the Water cohere, the Water, which runs out, accelerates that which runs into the Tube, and this laſt retards that which runs out; and ſo the Quantity of Water, which in a certain Time runs out of the Veſſel E, is a mean Quantity between the Quantities of Water that can run out at the ſame time from the Veſſels A and B.

EXPERIMENT 22. *Plate* 20. *Fig.* 10.

THE Veſſels A, E, and B, being made of ſome thin Metal, in the Proportions above-mention'd, fill with Water A and E; having open'd the Holes at the ſame Inſtant of Time, the Water of the Surface at E will deſcend faſter than at A; on the contrary, if you make uſe of the Veſſels E and B, it will deſcend faſter in the laſt than in the firſt.

LET the upper Hole of the Tube, by which it communicates with the Veſſel, remain as before; and the lower Hole be open'd wider: then a greater Quantity of Water will flow out, and the Water which goes into the Tube will be more accelerated; this Hole may be made ſufficiently wider without altering the Length of the Tube; inſomuch, that a greater Quantity of Water ſhall flow out from it than from the Veſſel B. In that caſe thro' the upper Hole of the Tube, at a ſmall Depth below the Surface of the Water, there flows out a greater Quantity of Water, than from an equal Hole four times the Depth. The ſame may be done by applying a longer Tube, without widening its lower Hole.

EXPERIMENT 22. *Plate* 20. *Fig.* 10.

TAKE the Veſſel F no way different from the Veſſel E, but in having the lower Hole of its Tube bigger; take alſo the above-mention'd Veſſel B. The Diameters of the Hole in the Bottom of this, and of the upper Hole of the Tube, which is join'd to F, are of four Lines ($\frac{1}{9}$ of an Inch) the lower Hole of this Tube is of five Lines. Let the Veſſels be fill'd with Water; and let the Water begin to run out of both at the ſame Moment; the Surface of the Water in F will deſcend faſter than that of B. The Veſſel B is about 16 Inches high.

End of the NINTH LECTURE.

ANNOTA-

ANNOTATIONS upon the Ninth Lecture.

1. [5.——*Improvements upon the Instrument.*]

MR. *CLARKE*, a Turner and Engine-Maker, who lives (or may be heard of) at *York-Buildings* Water-Works, having found that very few (even of the best) Hydrometers of Glass had their Stem so truly cylindrical, that one might depend upon their Divisions; and that the hydrostatical Balance (the only certain Instrument for finding the different specifick Gravity of Liquors exactly) cannot well be carried in the Pocket, and much less managed and understood by Persons not used to Experiments; was resolved to perfect the Hydrometer, for the Use of those that deal in Brandies and Spirits, that by the Use of the Instrument they may, by Inspection, and without Trouble, know whether a spirituous Liquor be *Proof*, *above Proof*, or *under Proof*, and exactly how much above or under; and this must be of great use to the Officers of the Customs, who examine imported or exported Liquors. Annotat. Lect. IX.

AFTER having made several fruitless Trials with Ivory, because it imbibes spirituous Liquors, and thereby alters its Gravity, he at last made a Copper Hydrometer, represented by *Fig.* 11. having a Brass Wire of about $\frac{1}{4}$ of an Inch thick going through, and solder'd into the Copper Ball B *b*. The upper Part of this Wire is filed flat on one side, for the Stem of the Hydrometer, with a Mark at *m*, to which it sinks exactly in Proof-Spirits. There are two other Marks, A and B, at top and bottom of the Stem, to shew whether the Liquor be $\frac{1}{10}$ above Proof, (as when it sinks to A) or $\frac{1}{10}$ under Proof, (as when it emerges to B) when a Brass Weight, such as C, has been screw'd on, to the Bottom at *c*. There are a great many such Weights of different Sizes, and marked to be screw'd on, instead of C, as K, *&c.* for Liquors that differ more than $\frac{1}{10}$ from Proof, so as to serve for the specifick Gravities in all such Proportions as relate to the Mixture of spirituous Liquors, in all the Variety made use of in Trade. N. B. *Proof Spirits, whether Brandy, Rum,* &c. *or* English *Spirits, weigh seven Pounds,* 12 *Ounces, per Gallon.*

THERE are also other Weights to be screw'd on for shewing the specifick Gravities quite to common Water, which makes the Instrument perfect in its kind.

N. B. *The round Part of the Wire above the Ball may be mark'd a-cross, as represented in* Figure 12; *that when the Weight, as* C, *which fits the Instrument for the Trial of River-Water that sinks it to* R W, *it may serve for Wines, or other Waters, which differ so little, that it may shew their Difference upon the Marks on the Stem, without putting on another Weight at bottom. At* S P, *Spring-Water*; *at* M I, *Mineral-Water*; *at* S E, *Sea-Water*;

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and at S A, *the Water of salt Springs may be denoted: whilst the Marks above,* viz. b r, r a, p o, m o, *come down to the Surface of the Water in the Vessel, in which the Hydrometer swims, when it is successively put into* Bristol-*Water, Rain-Water, Port Wine, and Mountain Wine.*

Plate 20. Fig. 12, 13.

PERSONS who are used to drink no other Liquor but Water, will by their Taste distinguish when there is but little Difference in the specifick Gravity; that being the purest and wholesomest Water, which is the lightest. I made an Hydrometer once for a Friend, to distinguish those Differences so nicely, that it would shew when one kind of Water was but $\frac{1}{40000}$ Part heavier than another. It was made in the following manner, as represented by *Fig.* 13. *Plate* 20. C B *b* is an hollow Glass Ball of about three Inches Diameter, with a small Ball under it, of about an Inch Diameter. There is a short small Neck at C, on which is fix'd a Brass Head with a fine Screw, into which the little Piece C *c* is to be screw'd, which is join'd to a Wire C A of about $\frac{1}{40}$ of an Inch Diameter, and 10 Inches long, and by sensible Marks divided into Inches, and Tenths of Inches. Having put a certain quantity of small Shot into the Ball *b*, so that when the Head C *c*, with its Wire C A is screw'd on, it shall sink as far as D (for example, five Inches) in River or soft Spring-Water; by observing how far this Hydrometer sinks lower in one kind of Water than another, one may know their different specifick Gravity to a 40000th Part, which corresponds with one Tenth of an Inch mark'd on the Stem A C. The Truth of this Nicety is prov'd in the following manner: When the Hydrometer floats in Water in the Jar I K L M, (*Fig.* 13.) the Surface of the Water cutting the Stem at D, if you lay a Grain Weight upon the Top of the Stem at A, the Instrument will sink so, that the Mark D of the Stem will settle one Inch under the Surface, which will shew that a Grain will sink it an Inch. When this Hydrometer is weigh'd in a Balance, it is found to weigh 4000 Grains, (and knowing before-hand that every Inch of the graduated Wire weighs 10 Grains) therefore the Part of it D C B *b c* D must weigh 3950 Grains. Now by what has been said *, a Bulk of Water equal to D C B *b c* D, the immers'd Part, weighs just as much as the whole Hydrometer, *viz.* 4000 Grains, therefore we do by this Instrument compare together the different Bulks of 4000 Grains of Water, according to their different specifick Gravities; and since the whole Instrument is sunk an Inch by the Weight of one Grain, and the Instrument will stand at one Tenth of an Inch, (the Difference that it will shew in Waters in which it floats) it is evident that it will distinguish the Tenth of a Grain in 4000, or the 40000th Part of the whole Bulk of the Water. *N. B.* By altering the Quantity of Shot in the Ball *b*, the Instrument may be prepar'd for the comparison of any two other Liquors, that are of nearly the same specifick Gravity.

* L. 9. N° 7. Page 189.

2. [8.——*How to do this, let the Proportion of Gold and Silver be what it will, will be shewn in the Notes.*] The Problem which *Archimedes* solv'd, in finding what Quantity of Gold was in the Crown, may be thus express'd.

LET a Mixture of two Metals be given; it must be found how much of each Metal is contain'd in the Mixture, if the Densities of the Metals and the Density of the Mixture be given.

LET

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Plate 20. Fig. 14.

LET the Denſity of the Metals be A B, A D; (*Plate* 20. *Fig.* 14.) and the Denſity of the Mixture be A C. Let alſo A L and L I be as the Bulk of the firſt and ſecond Metal in the Mixture. Let us ſuppoſe the Rectangles A F, L H, A G to be drawn.

THE Weight of the firſt Metal in the Mixture may be repreſented by the Rectangle A F; and in this caſe the Rectangle L H repreſents the Weight of the ſecond Metal; and the Figure A B F M H I A repreſents the Weight of the whole Mixture: this is alſo ſhewn by the Rectangle A C G I, which for that reaſon is equal to the Figure mention'd.

TAKING away from each ſide the Figure A C N M H I common to both, there remain the equal Triangles B N, N H; whoſe Sides are reciprocally proportional, F N being to N M, as N G to N C; that is, as L I to A L; therefore F M has the ſame Ratio to F N, as A I to L I. So that the Bulk of the Mixture: is to the Bulk of the ſecond Metal in the Mixture:: as the Difference of the Denſities of the firſt and ſecond Metals: to the Difference of the Denſities of the firſt Metal and the Mixture.

BUT the Weight of the whole Mixture is to the Weight of the ſecond Metal in the Mixture, in a Ratio compounded of the Denſities of the Mixture and the ſecond Metal, and the Ratio of the Bulk of the Mixture and the Bulk of the ſecond Metal in the Mixture; *i. e.* as the Product of the Denſity of the Mixture, by the Difference of the Denſities of the Metals, is to the Denſity of the ſecond Metal, multiplied into the Difference of the Denſities of the firſt Metal and the Mixture.

THIS Solution is founded upon the Suppoſition that each of the Metals keep their whole Bulk in the Mixture; for if ſome of the Parts of the one penetrate into the Pores of the other, the Solution will not be exact. For no Man can ſay that in every Mixture of Metals there is only an Appoſition of the ſmall Parts to each other; becauſe the Denſity of Copper may be increas'd by melting Tin with it: for Bell-Metal and Cannon-Metal, a Mixture of theſe two Metals in different Proportions, is ſpecifically heavier than Copper, and therefore I would recommend this chiefly for Gold and Silver.

3. [10.——*See the Notes, where this Problem is ſolv'd algebraically.*] Let the ſpecifick Gravities be denoted by theſe Letters,

The Fluid $= u$.
The heavy Body $= w$.
The lighter Body $= t$.

Their reſpective Bulks of the ſame Weight will be reciprocally proportional to thoſe Exponents: thus they may be expreſs'd,

Fluid $= w$.
Heavy Body $= u$.
Lighter Body $= \frac{uw}{t}$, to which let us ſubſtitute s.

NOW if the abſolute Weight of one of the Bodies be given, as here, the heavieſt, let us call it b, and the unknown Weight of the lighter x, their Bulks will be expreſs'd by $b\,u$ and $x\,s$, and their total Bulk $b\,u + x\,s$ muſt be equal to the Bulk of an equal Weight of Water $b\,w + x\,w$, whence we

have

Annotat. Lect. IX. have this Æquation, $bu + xs = bw + xw$; which being cleared, gives the Value of x. $bw - bu = xs - xw$.

Otherwise $\frac{bw - bu}{s - w} = x$, which was to be found.

Otherwise:

LET the Weight of the heavy Body $= b$, of the Cork $= x$, and the specifick Gravities of the heavy Body $b = 10$, of the Cork $= \frac{9}{4}$, of the Water $= 9$.

SINCE the Weights are as the specifick Gravities multiplied by the Bulks, the Bulks are as the Weights divided by the specifick Gravities; that is, $\frac{b}{10}$ and $\frac{4a}{9}$ will represent the Bulks of the heavy Body, and of the Cork; whence their joint Bulk will be $\frac{b}{10} + \frac{4a}{9} = \frac{9b + 40x}{90}$, which being multiplied by 9, (the specifick Gravity of the Water) must make a Weight of Water $= \frac{9b + 40x}{10}$, equal to the Weight of the Body and the Cork $= b + x$.

Whence $9b + 40x = 10b + 10x$;

That is $30x = b$

$\frac{b}{30} = x$. And when $b = 150$ ℔.: $\frac{150}{30}$ ℔. $= 5$ ℔. $= x$.

MOREOVER, to have the Proportion of the Bulk of Cork to the Bulk of the heavy Body, since those Bulks are as the Weights divided by the specifick Gravities, they will be as $\frac{150}{10}$, and $\frac{5}{2{,}25}$,

As 15 to 2,22, &c. or $2\frac{2}{9}$, or $\frac{20}{9}$,

or as 135 to 20.

3. [11.——*When remov'd into a lighter Fluid, or a Vacuum.*] From this Consideration a ludicrous Question may be seriously answer'd, *viz.* which is heaviest, a Pound of Feathers, or a Pound of Lead? Let a Pound be placed in the Scale of a Balance, and as many Feathers put into the other Scale, as will bring it to an *Æquilibrium* with the Lead. Then it may be safely pronounc'd, that those Feathers are heavier than the Lead: because when as much Matter in the shape of Feathers as the Lead contains, has been put into the Scale, the Feathers then lose of their Weight in the Air as much as an equal Bulk of Air weighs, (for example, $\frac{1}{4}$ of an Ounce, whereas the Lead loses only one Grain) and therefore an Handful or two of Feathers must be thrown into the Scale, to restore the *Æquilibrium* lost by the Bulk of the Feathers.

AND if we could take away the Air which makes this Difference, the Feathers would appear to be, what they really are, much heavier than the Lead. This will be better illustrated by the following

EXPERIMENT I. *Plate* 20. *Fig.* 15.

Plate 20. Fig. 15. IN a Glass Receiver E L L, standing on the Plate of the Air-Pump L L, there hangs up, from the Machine D E, a little nice Balance $a\,b$, in one of whose Scales is plac'd an Ounce of Lead p, and in the other a Cube of Cork c, which keeps

keeps it in *Æquilibrium.* Upon pumping out the Air from the Glaſs, the Cork *c* will over-weigh; and upon letting in the Air again, the *Æquilibrium* will be reſtor'd; becauſe the returning Air ſupports again what the Cork has more of Matter than the Lead. Annotat. Lect. IX.

5. [12.——*But that Nicety is overlook'd in common Uſe.*] As it follows from what we have ſaid, that he who buys wrought Gold in foul Weather, when the Air is light, by the Weight of Braſs, has a ſmall Advantage in compariſon of him who buys it when the Air is heavy: and he that buys Diamonds, on the contrary, will have an Advantage when the Air is heavy; what this Advantage is I will here ſhew. Firſt, let us conſider in general, that the ſpecifically lighter a Body is, the more additional Matter it muſt have to make *Æquilibrium* with a Body ſpecifically heavier; and when the Air is become much heavier, as we may ſee by the Barometer, ſuppoſe one Tenth, it will loſe ſtill more of its Weight than its Counterpoiſe, in proportion as it is ſpecifically lighter, which will diſturb the *Æquilibrium*, that cannot be reſtor'd without adding Matter to the ſpecifically lighter Body: thus therefore when Gold is counterpois'd with Braſs in foul Weather, (ſuppoſe when the Barometer ſtands at 28) the Braſs will become lighter in very fair Weather, (ſuppoſe when the Barometer ſtands at 31, and the Air has increas'd its ſpecifick Gravity $\frac{1}{10}$) and there muſt be more added to the Braſs (that is, the Weights muſt become more in Name) to make an *Æquilibrium*, to the Diſadvantage of the Buyer of the Gold. On the contrary, ſince Diamonds are ſpecifically lighter than the Braſs of which the Weights are made, in very fair Weather Matter muſt be added on the ſide of the Diamonds, (that is, Diamonds muſt be added) to reſtore the *Æquilibrium*, without calling the Weights more, tho' the Diamonds are increas'd in Quantity, to the Advantage of him who buys the Diamonds then. But an Example will ſhew how ſmall the Gain is in theſe Caſes.

Firſt for Gold. As the Braſs Weights commonly made uſe of are generally made of Pot-Metal which has Lead in it, they are ſpecifically heavier than common Braſs; ſo we will, for the Facility of Calculation, ſuppoſe that Metal of half the ſpecifick Gravity of Standard Gold.

A Bulk of Gold equal to a Pound of Braſs Weights, weighs two Pounds, and loſes one Grain of its Weight in the Air in foul Weather, (when the Barometer ſtands at 28 Inches.) A Weight of Braſs equal to this Gold is in Bulk ſeven cubick Inches; therefore loſes two Grains of its Weight in Air, (the Barometer ſtanding at 28 Inches.)

These two Metals are *in æquilibrio* in foul Weather; but the Weather becoming ſerene, and the Air $\frac{1}{10}$ heavier, the Barometer ſtanding at 31, the *Æquilibrium* is loſt, the Gold over-weighing; for the Gold now loſes but $\frac{1}{10}$ of a Grain more than it did in the laſt *Æquilibrium*, *viz.* one Grain and $\frac{1}{10}$ of a Grain: whereas the Braſs loſes $\frac{2}{10}$ of a Grain more than it did, *viz.* two Grains and $\frac{2}{10}$ of a Grain; which being $\frac{1}{10}$ of a Grain more than the Gold loſes, we muſt add that Weight to the Braſs, to reſtore the *Æquilibrium* in this Caſe, whereby we ſhall call the Gold $\frac{1}{10}$ of a Grain more than it is——and this

Annotat. Lect. IX. this in Value is the fifth Part of a Penny, reckoning Gold at Two-pence a Grain: or one Part in 115200.

For Diamonds, this is the Calculation.

If instead of the Gold we make an *Æquilibrium* in the Scale opposite to the two Pounds of Brass Weights with Diamonds, their Bulk will exceed that of the Brass about three times, *viz.* in a reciprocal Proportion of their specifick Gravities. Then the Brass losing of its Weight in foul Weather two Grains, the Diamonds will lose of their Weight six Grains.

This being the State of the *Æquilibrium*; in fair Weather (the Barometer being at 31 Inches) the Brass loses two Grains, and $\frac{2}{10}$ of a Grain, and the Diamonds lose six Grains, and $\frac{6}{10}$ of a Grain, so that the *Æquilibrium* is broken by $\frac{4}{10}$ of a Grain, which cannot be restor'd without adding $\frac{4}{10}$ of a Grain on the side of the Buyer, equal in Value to about one Part in 28800.

6. [13.——*By an Horse-Hair*, &c.] Horse-Hair is made use of, because it is of the same specifick Gravity as Water.

Plate 19. Fig. 14. 7. [26.——*The Manner of doing it in the Notes*, &c.] See *Plate* 19. *Fig.* 14. The thing requir'd here is to make the Bubble B go down to the Bottom at *b*, and the Bubble A go up to *a*, by pouring in Water from the Vessel C. In order to do this, things are to be thus prepar'd: Let the Water E D be made very salt, and let the Bubble B, when it is so pois'd with Water in it as but just to swim in the Water E D, be hermetically seal'd, so that it may sink as soon as the Medium becomes thinner, by the pouring in of more Water. The Bubble A made just specifically heavier than the salt Mixture, must have its Stem left open. The Change of Places will be made by pouring in warm Water from C. The Heat that warms the whole Fluid rarefying the Air in the Bubble A, in its Expansion it will drive out some of the Water contain'd in it, and thereby becoming specifically lighter, rise up to *a*; whilst B sinks down to *b*, because the whole Medium being made lighter by the Mixture of fresh Water, B, which was but just buoyant before, will be no longer sustain'd.

N. B. *This must not be kept long in the Condition in which it is after the Experiment; because upon the cooling of the Liquor the Air in* A *will be condens'd again, and the Bubble drawing in Water, will sink.*

[30.——8. *A Rocket rises by the unequal Pressure of the expanding Gun-Powder.*] As a great many People mistake the Cause of Rise of a Rocket, supposing that the Impulse of the Flame against the Air causes a Re-action which pushes up the Rocket; I was willing here to rectify the Mistake, since the Rocket would rise better *in vacuo*, the Air having nothing to do in its Rise, but rather hindering it by its Resistance against its upper Part. For first, if we suppose the Air's Resistance at the Mouth of the Rocket equal to the Impulse of the Flame, it will be as if the Rocket had no vent; and therefore in that case it must either burst or remain immoveable. If the Impulse be greater, the Air's

Re-action againſt the Flame coming downwards, cannot impel the Rocket upwards, unleſs the Flame ſhould be a ſolid Body. Laſtly, if the Impulſe ſhould be leſs than the Force of the Air, no Flame can come out of the Rocket.——To underſtand the true Reaſon of the Riſe of a Rocket, we muſt firſt conſider it as if it had no vent at the Choak or Mouth A, (*Plate* 20. *Fig.* 16.) and was ſet on fire in the conic Space *bcd*; the Conſequence of which wou'd be, either that the Rocket wou'd burſt in the weakeſt Place, or that if all the Parts were equally ſtrong, and able to ſuſtain the Impulſe of the Flame of the Powder, the Rocket would remain immoveable. Now, as the Force of the Exploſion or Flame is equal every way, let us ſuppoſe its Action towards A and towards E to be able to lift 40 Pounds; but as the Directions of thoſe Forces are equal and contrary, they will deſtroy each other's Action: then if you imagine the Rocket open'd at A, the Action of the Flame downwards is taken quite away, and there remains a Force equal to 40 Pounds acting upwards in the Direction A*c*E, which carries up the Rocket with its Stick FG. This will appear by obſerving that when the Compoſition of the Rocket is very weak (ſo as not to give an Impulſe greater than the Weight of the Rocket and Stick) it will not riſe; if the Compoſition be only ſlow, the Rocket will not riſe at firſt, whilſt the Action of the Flame upwards is only againſt *c*, the Vertex of the hollow Cone; but when the Compoſition is conſum'd as far as *h i*, the Flame acting upwards againſt a greater Surface, namely againſt *hi*, the Rocket will then riſe up. The Uſe of the Stick is to keep it perpendicular; for if the Rocket ſhould begin to tumble, moving round the Point A, (which is the common Center of Gravity of the Rocket and Stick) the End G of the Stick FG wou'd bear ſo much Air, and with ſuch Velocity, upon account of its Diſtance from A, that the Re-action of the Air by its Reſiſtance, muſt reſtore the Stick, and conſequently the Rocket, to a perpendicular Poſition; but when the Compoſition within the Rocket is quite conſum'd, and the Impulſe upwards is ceas'd, the common Center of Gravity will be brought down to F, the Velocity of G diminiſh'd, and that of E increas'd; ſo that the Rocket will tumble over, and fall with the End E downwards. All the while that a Rocket burns, the common Center of Gravity is getting downwards, the faſter and the lower, the lighter the Stick is; ſo that ſometimes it tumbles over before it be burn'd out; but when the Stick being heavier, the Weight of the Rocket bears a leſs Proportion to that of the Stick, the common Center of Gravity will not get ſo low, and the Rocket will riſe ſtreight, tho' not ſo faſt.

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Plate 20. Fig. 16.

The Mean between theſe muſt be found by poiſing the Rocket and Stick acroſs your Finger: if you wou'd uſe a light Stick, poiſe ſo as to leave the Center of Gravity juſt at A, the Mouth of the Rocket; and for a heavy Stick, let not the Center of Gravity be lower than 5 or 6 Inches off from the Mouth.

After having made and explained the Experiment of the 19th Figure of *Plate* 19. where little hollow Images of Glaſs are made to riſe and fall, turn, and dance in a Jar of Water, according to the different Preſſures * made with the Hand on the Bladder, which is tied over the Top of the Glaſs: I commonly

* L. IX. N°. 20. Page 210, 211.

Annotat. Lect. IX. monly set the Jar up between two Pillars in a Frame which stands near me, and screw it fast down under the top Cross-bar, with the two Screws C and D, as to secure it from being broken because it is tall and tottering, but really with another view. For in about a quarter of an Hour'sTime, after having made some other Experiments; I get up from the Table, and standing at a distance from the Jar, I speak to the Images, which rise and fall at the Word of Command in the same manner as they did when I press'd my Hand on the Bladder before; which generally very much surprises some of my Audience, when they find I have no communication with the Figures: but as this latter Part is rather a *jugling Trick* and a mere Amusement, than a Philosophical Experiment, I intended to have omitted the Description, and even the Mention of it; but several of my Friends desired that I wou'd publish the Contrivance; to shew how much one may be impos'd upon by Confederacy, and beware of such Deceits in Matters of Consequence: The Generality of Mankind admiring that most, which they understand least. I complied the more readily with this; because my Business for these 33 Years past has been to clear up Phænomena, and explain the Operations of Nature and Art.

The 19th Figure of *Plate* 20. is the Frame above-mention'd, into which the Glass Jar may be put at pleasure, which Frame is prepar'd beforehand in the following manner: On the Board AB (*Plate* 20. *Fig.* 19.) there is a little Hollow in the Middle for the Bottom of the Glass Jar to stand in; and an Hole *g* in the Bottom of the top Cross-Piece EF, but not visible, to receive the Top of the Glass that is cover'd with Bladder. This Hole *g* is shewn in *Fig.* 21. which represents the lower Board of the cross Top-Piece, consisting of two Boards (see *Fig.* 20.) BB*sb*, of which the upper one hides the above-mention'd Hole, and the rest of the Contrivance, and Machinery, which is as follows.——*Fig.* 19. EF is a Leaver that has its Center of Motion E in the Screw Part of the Pillar AC, in the Hollow between the two Boards of the Top-piece; (See *Fig.* 20.) where one may see at *g* the pressing Piece under the Middle of it (mark'd with the same Letter *g* in all the Figures) which is drawn down to press like an Hand on the Bladder of the Jar by a String S fasten'd to the End F of the Leaver, and farthest from the Center of Motion E. When the String is slacken'd, the End F of the Leaver is rais'd up again by a Spring *s* (see *Fig.* 19, & 20.) to ease or quite take off the Pressure on the Bladder of the Jar from the pressing Piece, which it does well, as that Piece is a Segment of a Sphere of Wood, shewn best in *Fig.* 20. The End F of the Leaver moves in a Slit under D in the screw'd Part of the Pillar BD to rise and fall in, but hidden in the Hollow of the cross Top-piece. The String fasten'd to the Leaver at that End is continued down the Pillar DB, which is hollow all the way, and so thro' an Hole H in the Table TT, whereon the Frame is set. This String goes round the Pully P under the Table at S, from whence it is convey'd to another Pulley under the farther Side of the Table, where it is managed by some of the Audience who sit on that side and are in Confederacy with the Person that shews the Experiment, or speaks to the Images. *N.B.* All kind of Pressures and Jerks may be perform'd by this String and the Re-action of the Spring *s*. *N.B. Fig.* 21. shews the horizontal Section of the Leaver and Pillars, and Jar.

9.

9. [33.——Dr. Hales *has since——propos'd another Sea-Gage for vast Depths*, &c.] I shall here give it in his own Words, from his *Vegetable Staticks*.

A DESCRIPTION OF AN INSTRUMENT *to measure the Depths of the Sea.* By Dr. *Stephen Hales*.

' 1. IN my first Volume under Experiment 89. 209, I have propos'd a Me-' thod for finding the Depth of the Sea, where the Line can't be used. ' Dr. *Desaguliers* has put it in practice, and shew'd the Experiment of it to ' the Royal Society, with a Machine that he has contriv'd, and of which he ' has given a Description in the *Philosophical Transactions*, N° 405. I shall ' here more particularly describe how to prepare and graduate this Sea-Gage.

' 2. SUPPOSE there be an Iron or Copper Tube, or a Musket Barrel of any ' length; as fifty Inches, having its upper End well closed up: If this ' Tube be let down, in this Position, about thirty-three Feet in the Sea, for ' a Column of Sea-Water of that Height is nearly equal to the middle Weight ' of our Atmosphere; then consequently from a known Property of the Air's ' Elasticity, it will be compressed into half the Space it took up before, so ' that the Water will ascend half the way up the Tube. And if the Tube ' be let down thirty-three Feet deep, the Air will be compressed into one ' third of its first Dimension, and so on $\frac{1}{4}$th, $\frac{1}{5}$th, $\frac{1}{6}$th, *&c.*

' THE Air being constantly compressible in proportion to the incumbent ' Weight, whence by knowing to what Height the Water has ascended in the ' Tube, we may readily know to what Depth the Tube has descended in the Sea.

' 3. NOW to measure the Depth of one of these Columns of Sea-Wa-' ter, whose specific Gravity to pump Water is found to be as forty-one to ' forty: first by a Line let the Iron Tube, with a Weight at its Bottom, ' sink about thirty-three Feet, which Depth in Salt Water will nearly ' answer to the Weight of the Air at a mean Height of the Barometer; ' then draw up the Tube, and observe how far the Water rose; if thirty-' three Feet of Water is equal to one Atmosphere, then will the Water rise ' so high as to fill exactly one half of the Tube: but if the Water rise higher, ' or lower than half way, then by the Rule of Three say, As the Number ' to which the Water rises is to one, so is thirty-three to the Number of ' Feet, measuring the Depth of the Column required. For Example, sup-' pose the Water rises (when the Tube is let down thirty-three Feet) only ' nine Tenths of half way; then say, 9 : 10 :: 33 : $36\frac{2}{3}$ Feet, the Depth of ' each Column, which being once known, the Number of Columns of Water ' is to be multiplied by this Number of Feet, whereby the Depth of the Sea ' in Feet will be known.

' 4. BUT since when the Instrument has descended to the Depth of ninety ' nine Columns, or ninety-nine times thirty three Feet, the Air will be com-' pressed into the $\frac{1}{100}$th Part of fifty Inches, that is, half an Inch, the Divi-' sions both for some Space below, and also above that, will be so very small, ' that the Difference of several Columns Depth of Water will not be sensible; ' so that an Instrument of no greater Length than this, would scarcely give ' an accurate Estimate of half a Mile's Depth, that is, 2640 Feet, or eighty

Lect. IX. 'Columns Depth of Water. The lengthening therefore of this Instrument 'to four, five, or ten times its Length, would obviate this Defect, and make 'the Difference of the Degrees of Descent more sensible on the Instrument. 'But since it is impracticable to make a metalline Tube of so great a Length, 'and if it were made, it would be so unwieldy as to be easily broken; it is 'proposed therefore to obviate these Difficulties by the following Method, '*viz.*

'5. Let there be a globose metalline Body made of Copper, whose Capa-'city within Side may be equal to nine times the Capacity of the metalline 'Tube: Let this globose Body be firmly screwed to the metalline Tube with a 'leathern Collar, well soaked in some unctuous Matter, thereby to secure 'that Joint in the most effectual manner.

'6. There must be a Hole at the Bottom of the Copper Globe opening 'into a metalline Tube soldered to that Hole, which Tube must be three or 'four Inches Length, that it may be immersed in a proper metalline Cistern, 'full of some tinged unctuous Matter, as Oil, or the like, which being speci-'fically lighter than Sea-Water, will swim upon it, and consequently will 'daub the Inside of the Iron Tube, as far as the Water was impell'd up it. 'And in order to know that Height, there must be fixed a slender Rod of 'Brass, Iron, or Wood, in the middle of the Iron Tube from end to end, 'with a Knob at its upper end, both to keep it at that end in the middle 'of the Tube, and also to prevent its being besmeared by the Sides of the 'Tube, when it is drawn out to see, by the Mark of the unctuous Matter on 'the Rod, to what Height the Water had been pressed up the Tube.

'7. The Capacity of the Tube must be estimated by pouring Water in 'when the Rod and metalline Diameter are fixed in their Places.

'8. Now since the Copper Globe is supposed to contain nine times as much 'Air as the Tube, which is the same thing as if the Tube was nine times as 'long; therefore the Air in the globose Vessel will not be forced within the 'Capacity of the Tube, till the Vessel has descended to the Depth of nine 'Columns, or nine times thirty-three Feet: for then the Air will be com-'pressed within one tenth of the Space it at first took up.

'9. Supposing therefore the Instrument to have descended to the Depth of 'ninety-nine Columns of Water, or ninety-nine times thirty-three Feet, *viz.* '3267 Feet, then the Air will be compressed within $\frac{1}{100}$th Part of five hun-'dred Inches, (for the Capacity of the whole Vessel was supposed equal to a 'Tube of that Length) that is, within five Inches of the Top of the Tube; 'and consequently the Rod will be found tinged with the coloured Oil within 'five Inches of its Top.

'10. Suppose again, the Instrument to have descended to the Depth of an 'hundred and ninety-nine Columns of thirty-three Feet each, then the Air 'will be compressed within the $\frac{1}{200}$th Part of the whole, that is, nearly 'within two and a half Inches of the Top of the Tube. In this case the In-'strument will have descended 6567 Feet, that is, a Mile and a Quarter and 'an hundred and thirty two Feet.

'11.

'11. Suppose again the Machine to have deſcended to the Depth of three 'hundred and ninety-nine Columns, then the Air will be compreſſed within '$\frac{1}{400}$th Part of the whole, that is, nearly within one Inch and a Quarter of 'the Top of the Tube: In this caſe the Machine will have deſcended two 'Miles and a half, wanting fifty-three Feet; which may probably be the greateſt 'Depth of the Sea.

'12. But if there were occaſion to explore greater Depths than this, it 'might, we ſee, be done with tolerable Accuracy, by enlarging the Capa-'city of the globoſe Veſſel, which might be done without making it very 'cumberous. To ſuppoſe the Diameter of the Tube were about $\frac{3}{4}$ths of an 'Inch, *viz.* common Muſket-Barrel Bore, and that it were fifty Inches long, 'if the globoſe Veſſel were nineteen times as big, it would not in that caſe ex-'ceed the Bulk of three Gallons. But the bigger the globoſe Veſſel, the 'greater care muſt be taken to ſecure well the Screw where it is joined to the 'Tube, that no Air paſs that way.

'13. The bigger the globoſe Body is, the more weighty it ought to be, 'thereby the more effectually to keep it in a low depending Poſture; elſe the 'Buoyancy of its contained Air might raiſe it as high or higher than the 'upper Part of the Machine, whereby Water ruſhing in to the top of the 'Tube, no Obſervation could be made, the Rod being thereby moiſtened 'from end to end. When one Experiment has been made, the Rod and 'Tube muſt be wiped very clean before another be repeated.

'14. This Sea-Gage being thus prepared, a large Buoy muſt be fixed to 'it, which ought to be a large Piece of ſolid Fir, or any other light ſolid 'Wood, well covered with Tar, to prevent any Water's being preſſed into the 'Sap-Veſſels: For I have found by experience, that Wood which was conſi-'derably lighter than Water, has, by being greatly compreſſed in Water, 'become immediately ſpecifically heavier than Water; for the conſtituent 'Parts of all Vegetables are ſpecifically heavier than Water. If the Buoy be 'made of a Bladder or hollow Globe, with its Orifice inverted downwards, 'the Air in them will be compreſſed to ſuch a degree, at great Depths, as 'thereby to make the buoyant Body become ſpecifically heavier than the 'Sea-Water, which would prevent its re-aſcending to the Surface of the Sea; 'for which Reaſon alſo the Buoy ought to be able to buoy up the Inſtrument 'when full of Water. Beſides, if the Buoy, when it riſes again, do not ap-'pear ſome conſiderable Height above the Water, it will not eaſily be diſ-'covered: for it is probable, that from great Depths it may riſe at a conſi-'derable diſtance from the Ship, though in a Calm. To make the Buoy 'therefore more viſible at a diſtance, it will be proper to fix acroſs each other, 'at the top of the Buoy, broad Fans of Tin, painted either black or white, 'as ſhall be moſt convenient.

'15. For greater Accuracy, it will be needful firſt to try this Sea-Gage, 'at ſeveral different Depths, down to the greateſt Depth that a Line can 'reach, thereby to diſcover, whether or how much the Spring of the Air is 'diſturbed or condenſed, not only by the great Preſſure of the incumbent

Annotat. Lect. IX. ‘ Water, but also by its Degrees of Warmth or Coldness at great Depths, ‘ and in what proportion at different known Depths, and in different Lengths ‘ of Time, that an allowance may accordingly be made for it at unfathomable ‘ Depths.

‘ 16. And because it is probable that the Temper of the Air, when the ‘ Experiment is made, will be either warmer or colder than that of the Sea ‘ at a considerable Depth; it will therefore be advisable to let down the In- ‘ strument with a Line to a good Depth, there to continue for some time, ‘ till the Air in it may be supposed to come to the same Temper with the ‘ Sea-water: Then the Machine is to be pulled up so far above Water, as to ‘ let the Air freely pass either in or out of the Globe and Tube, according as ‘ the included Air shall either have dilated or contracted. Then instantly let ‘ the Machine loose, to drop down to the Bottom of the Sea, which it will do by ‘ means of a sinking Weight of Ballast, which must be fixed in the following ‘ manner, *viz.*

‘ 17. The sinking Weight of Ballast must be so fixed to the Machine, by ‘ means of a Catch-Hook, that as soon as the Weight touches the Ground at ‘ the Bottom of the Sea, the Catch may then, by means of a Spring, let go ‘ its hold; whereby the Buoy will be at liberty to carry the Machine up to ‘ the Surface of the Water.

‘ 18. The Weight of the sinking Ballast ought to be so proportioned, as ‘ to be just sufficient to sink the Machine at first; for as the Machine descends, ‘ it grows continually specifically heavier, by reason of the Condescension of ‘ the Air in its Cavity, on which account its Motion will be accelerated, as ‘ well as on account of the incessant Action of the Power of Gravity upon it; ‘ so that if this gravitating Power far exceeded the contrary Renitency of the ‘ Buoy, it would strike the bottom of the Sea with such a force, as might ‘ endanger the breaking of the Machine.

‘ 19. It would therefore be adviseable first to let down the Buoy with ‘ something of equal Weight with the Machine, and an Iron Rod intervening ‘ between the Machine and the Buoy, thereby to guess by the bending or ‘ not bending of the Rod, with what Degree of Force it might strike the ‘ Bottom of the Sea. And if the Force should be found to be great, I be- ‘ lieve it might be advisable to fix a Pole between the Machine and the Ballast, ‘ of such a Degree of Strength, that it would break before it could give Re- ‘ sistance enough to hurt the Machine: This would greatly break its Force ‘ against the Ground. Some of the Sand or Earth at the bottom of the Sea ‘ should be brought up as in common Soundings, with Tallow at the bottom ‘ of the Plummet.

‘ 20. It would be adviseable also to keep an exact Account of the Time ‘ of the Machine's Stay under Water, which may be done by a Watch that ‘ beats Seconds, or by a Pendulum vibrating Seconds, which must be three ‘ Feet, three Inches, and one Fifth of an Inch long, between the middle of ‘ the Bob, and the upper End of the Line.

'21. Dr. *Hook*, in the Philoſ. Tranſ. *Lowthorp*'s Abridgment, *Vol.* 2. *P.* 258. found upon trial, that a leaden Ball which weighed two Pounds, being fixed to a wooden Ball of the ſame Weight, and both let down in 14 Fathom Water, they reached the Bottom in 17 Seconds, and the detached wooden Ball aſcended to the Surface of the Water in 17 Seconds more; ſo that if the Machine above deſcribed deſcended, and aſcended to greater Depths with the ſame Velocity, it would reach to the Depth of a Mile in 17 Minutes, and re-aſcend in the like time. But ſince the buoyant Body may return faſter to the Surface of the Water than it deſcended, therefore Eſtimates from the time of the Bodies keeping under Water will be very uncertain: Yet when frequently compared with the Eſtimate which is made, from the Height of the Water in the Gage-Tube; a Rule may perhaps be formed from thence, eſpecially if the whole Machine be always the ſame, and the ſinking Ballaſt be always of the ſame Weight and Size: as ſuppoſe the Ballaſt were put into globular earthen Veſſels, made all of the ſame Diameter.

'22. That the Sea is not many Miles deep is probable from hence, that all the great Oceans are here and there interſperſed with Iſlands; an Argument that, though as far as the Sounding-Line has reached, the Sea is found to be deeper and deeper, the farther from the Shoar, (tho' with ſome Unevenneſs) which would come to a great Depth indeed, if it continued on ſo, from one Boundary of the vaſt Ocean to the other; but the interſperſed Iſlands prove that it is not ſo.

'23. If we ſuppoſe the Sea to deepen from the Shoars in nearly the ſame Proportion that Land riſes from the Shoars, then from the following Eſtimate the greateſt Depth of the Sea will not exceed five or ſix Miles. For ſince ſlow Rivers are found to have a Fall of about a Foot in a Mile, if we ſuppoſe the River *Niger* in *Africa* (which is one of the longeſt Rivers in the World, and runs about 2400 Miles in Length) to fall at the rate of four Feet each Mile, then its whole Fall, from its Riſe to its diſcharging itſelf into the Sea, will be 1.81 Miles. If it falls at the rate of ſix Feet a Mile, then its whole Fall will be 2.72 Miles. If eight Feet each Mile, its Fall will be 3.72 Miles. But if the Fall be ſet at ten Feet each Mile, then the Fall of the River will be 4.54 Miles; which is a large Allowance, and may therefore well include the Height of the Tops of the Mountains, from whoſe Sides thoſe Springs break forth: The higheſt Mountains being eſtimated to be ſcarce $\frac{1}{859}$th of the Earth's Semi-diameter. If we ſuppoſe that the whole Quantity of Earth, which is above the Level of the Surface of the Seas, were equal to the whole Bulk of the Waters in the Baſis of the Seas, then ſince the Sum of the Expanſe of all the Seas is conſiderably more than the Sum of the Surface of all the Earth on this Globe, the general Depth of the Sea muſt therefore be conſiderably leſs than the general Height of the Earth above the Surface of the Sea.

'24. To this Method of taking the Depth of the Sea it may reaſonably be objected, that tho' it has been found by Experience, that in leſſer Degrees the Air is compreſſible, in proportion to the incumbent Weights, yet it is to

' be

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'be feared, that in greater Degrees of Compreſſure this proportional Compreſſibility would not hold true, by reaſon of the many watery, and other heterogeneous Mixtures in the Air, which would hinder its equable Compreſſibility. 'Yet, ſince the irregular Degrees of its Compreſſibility are not yet certainly 'known, it might be well to try the Inſtrument firſt to the greateſt Depth a 'Line can be let down, which I find has been to 400 Fathom, in which caſe 'the Air would be compreſſed with more than 72 Columns of Water, each 'equal to the Weight of the Atmoſphere, ſo that the Air would be compreſſed into $\frac{1}{73}$d Part of its natural Bulk, in which caſe the Denſity of that 'Air would be to Water, as 1 to 11.64. When the Air is compreſſed with 'the Weight of 99 Columns of Water, at the Depth of 3267 Feet, or half a 'Mile and 627 Feet, then its Denſity will be $\frac{1}{8}$th of Water; at 199 Columns Depth, or a Mile and a quarter and 132 Feet, its Denſity will be '$\frac{1}{4}$th of Water; and at 399 Columns Depth, or two Miles and an half wanting 53 Feet, its Denſity will be $\frac{1}{2}$ of Water.

'25. I HAVE compreſſed Air with a Weight equal to 37.44 Atmoſpheres 'in the following Manner, *viz.* I took a Glaſs Tube, which was cloſed at 'one End, the Length of its Cavity 4.06 Inches, its Diameter 0.16. being 'firſt conterpoiſed in a Scale, and then filled with Water, the Weight of the 'Water it contain'd was one Dram and ſix Grains. The open End of this 'Tube I immers'd in a ſmall Viol, at the Bottom of which was ſome Mercury, with a little Spirit of Turpentine, which was tinged with Indigo: 'The Viol and Tube were let down into a large Bomb full of Water, which 'was placed under a Cyder-Preſs; then there was put into the Orifice of the 'Bomb a well-turned Plug of Holly-wood, which was impelled ſo forcibly 'into the Bomb by the Screw of the Preſs, that Water ouzed thro' the Pores 'of the Plug, notwithſtanding it had been dipt in melted Cement made of 'Bees-Wax and Turpentine. When I took the mercurial Gage out of the 'Bomb, I found the tinged Turpentine had riſen ſo high, as to have compreſſed the included Air within the Space of 0.12 Inch of the Top of the 'Tube; that is, the 38.44th Part of its Capacity; ſo that the included Air 'was compreſſed with 37.44 Atmoſpheres, equal to the Preſſure of 1235.5 'Feet, or 205.9 Fathom deep in the Sea: ſo that the Denſity of this Air was 'to that of Water, as 1 to 22.7.

'26. Air, when thus greatly compreſſed, has not been obſerved, either to 'enter the Mercury in the Gage, nor to paſs thro' the Pores of the Glaſs; nor 'has it been found to be fixed by any known Degrees of Compreſſure, or 'Cold.

'WHAT Effect ſuch an extreme Preſſure as two or three Miles Depth of 'Sea-Water would have on it, we can know only by Experience; which 'might probably be tried in the manner here propoſed without much difficulty.

'27. THE greateſt Degree of Compreſſure that I have been able to give 'Air was in the following manner, *viz.* Having in froſty Weather placed the 'above-mentioned Bomb, with the Mercurial Gage in it, under the Cy-

'der

'der Press, in the same manner as before described, I then covered the 'Bomb with a large Quantity of pounded Ice, which had half its Quantity 'of common Salt mixed with it: In a little time this great Degree of Cold 'burst the Bomb into three Pieces from Top to Bottom; these Pieces opened 'wide, by falling asunder, but their lower Parts touched each other; an evi- 'dent Proof that the Water, tho' compress'd to so great a Degree as to burst 'the Bomb, yet had very little Elasticity in it. Annotat. Lect. IX.

'28. THE Bomb was lined all over within-side with a Shell of Ice, which 'was about $\frac{3}{4}$ of an Inch thick; it was full of Air-Bubbles.

'29. As to the Viol and Mercurial Gage, they were broken into many 'Pieces, and all the Pieces of the Tube or Gage were daubed within-side with 'Turpentine, and Par icles of Mercury, to the very top of the Tube, which 'was frozen at each End into the Shell of Ice.———As the Water in 'the middle of the Bomb was not frozen, this Experiment might easily be 'repeated, without danger of breaking the Gage, or Viol, *viz.* by fixing 'them to a small Stick of equal Length with the Diameter of the Bomb, 'by which means they would be sustained within the Limits of the unfrozen 'Water.

'30. WE may from this Experiment make some Estimate of the Force 'which was requisite to burst the Bomb, and consequently of the Degree of 'Compressure which the Air in the Gage sustained, *viz.* the Diameter of the 'Bomb within-side was 6 + $\frac{1}{2}$ Inches, the Thickness of its Substance at its 'Orifice 1.2 Inch; its Thickness at the Bottom was 1.9 Inch. Now sup- 'posing the Substance of the Bomb to be all over of the same Thick- 'ness with its thinnest Part, *viz.* 1.2 Inch; then the Area of the Ringlet 'which cuts that Substance transversely in its biggest Circle will be equal 'to 29.72 square Inches: That I may therefore make some Esti- 'mate of the degree of Coherence, of the Substance of the Bomb in this 'Ringlet, I shall found my Calculation on Mr. *Muschenbroek*'s 77th Experi- 'ment, in his *Introductio ad Cohærentiam Corporum, P.* 505. where he found 'that Iron Wire, whose Diameter was $\frac{1}{10}$ of a *Rynland* Inch, was pulled 'asunder with four Hundred and Fifty Pounds Weight. The Wire being 'made of hammered Iron, was probably tougher than the Bomb, which is 'made of cast Iron; I have therefore made a large Allowance for this, in 'leaving a great Part of the Thickness of the Bomb out of this Estimate.

Mr. de Buffon, *who translated the Vegetable Staticks into* French, *having found a Mistake in the Calculation concerning the Bomb, gave another Calculation, which I translated for this Place; but finding a Mistake also in his Calculation, I have set it right now. I had not mention'd this, but that I was unwilling to pass for an unfaithful Copier, or Translator.*

Taking the Diameter of a Circle to the Circumference, as 7 to 22.

THE inner Diameter of the Bomb was 6 and $\frac{1}{2}$ Inches, its Thickness one Inch and $\frac{2}{10}$: The Area therefore of the transverse Section of that Thickness will

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will be $\frac{209888}{15680}$; that is, very near $13\frac{2}{5}$ square Inches: which is found by taking the Superficies $\frac{1859}{56}$ of the inner Circle, whose Diameter is $6\frac{1}{2}$ Inches, from the Superficies $\frac{13043}{280}$ of the outward Circle, whose Diameter is $7\frac{7}{10}$ Inches.

THE *Rynland* Foot is to the *London* Foot, as 139 to 135; the Diameter of the Iron Wire was $\frac{1}{10}$ Inch *Rynish*; that is, $\frac{139}{1350}$ Inch *English*; therefore the Area of its transverse Section will be $\frac{212531}{25515000}$, very near $\frac{21}{2551}$ Inch square. I say therefore, since 450 Pounds of *Amsterdam* were required to break Iron of a Thickness equal to $\frac{21}{2551}$ Inch, how many of the same Pounds will be required to break a Thickness equal to $13\frac{2}{5}$ Inches? And by the Rule of Three I find there must be 732501 *Amsterdam* Pounds to break the Bomb; that is, $681225\frac{93}{100}$ *English* Pounds, the *Amsterdam* Pound being to that of *London*, as 93 to 100. Now the Area of the inner Circle of the Bomb is $33\frac{11}{56}$ square Inches, and the Weight of a Column of the Atmosphere upon a square Inch is 15 Pounds five Ounces, or thereabouts: Therefore the Weight of the Atmosphere upon the total Area of the Circle, is of 508 Pounds and six Ounces, very near: I therefore divide 681225 by 508, and I have $1340\frac{505}{508}$, about 1340; that is, the Air contained in the Tube was compressed by a Force equal to the Weight of 1340 Atmospheres, consequently it was reduced to a Space 1340 times less than it had in its natural State.——This is true only by supposing the Iron of the Bomb as strong as that of the Wire: but as beaten Iron, of which it was made, is stronger than cast Iron, of which the Bomb was made; you must proportionably diminish the Number 1340. This Diminution is necessary, and cannot be compensated with the greatest Thickness of the Bomb: For if in a Vessel there is one place thinner than the rest; this is enough to make us suppose it every where of that Thickness, when we consider the Resistance made to a Fluid, which presses equally every way.

LECTURE

LECTURE X.

HYDROSTATICKS.

A further Consideration of the Nature of the Air, in respect to several of its Properties, which we have not yet taken notice of; together with the Observations and Experiments to shew those Properties; and a Description of such Machines and Instruments as serve to apply them to Use.

N. B. THIS is call'd by some, The Doctrine of *Pneumaticks*; but we continue it under the Head of *Hydrostaticks*, because Air is a Fluid, whose Pressure and Resistance acts like Water and other Fluids, tho' Water is not compressible like Air, nor elastick, unless when Heat is applied to it. But yet we shall particularly consider all that Air has belonging to it different from other Fluids.

1. IT is pretty strange that the Ancients, who were no Strangers to the Nature of Winds, and knew a great deal of their Force, were yet entirely ignorant of the Weight and perpendicular Pressure of the Air. This is evident, because they attributed the Cause of Water rising up in Pumps, or any Liquor being drawn up into Syringes (commonly call'd *Syphons* upon that account, while Pumps were call'd Sucking-Pumps) to Nature's *Abhorrence of a Vacuum*, saying, that it fill'd up with Water the Pipes of Pumps under the moving Bucket or Piston, rather than suffer any empty Space. Lect. X.

THE Syringe was in use, and this Notion concerning its Suction obtain'd long before *Ctesibius* (the Son of a Barber at *Alexandria*) invented the Pump: and tho' he made the Forcing-Pump, where the Air visibly drives the Water, as well as the Sucking-Pump, he only thought, that the Air put into a visible Motion might drive the Water; but had no notion of its Action, or perpendicular Pressure, when it was stagnant, and

Lect. X. seem'd to stand wholly still: he acquiesced in the general Opinion of the *Fuga Vacui*. Nay, *Galileo* himself, who was the first that found out that Water did not rise in Pumps above 33 or 34 Foot higher than the Water in the Well from whence it was drawn, (tho' the Pipe of the Pump was 40 Foot long, and the Bucket or Piston work'd at that Height above the Water) only concluded from that Observation, *that Nature abhorr'd a Vacuum but to a certain degree.* But his Scholar *Toricelli*, who succeeded him as Mathematician to the Duke of *Florence*, guess'd that the Air press'd, and confirm'd it by an Experiment which made him famous, and has ever since been called by his Name. He was led to it by some such Considerations as the following.

Plate 20. *Fig.* 17, & 18.

Plate 20. Fig. 17 & 18. 2. TAKING notice of two Pumps PP and PP of very different Bore and different Heights, as the Pump of *Fig.* 17. of only one Inch Bore, and about 40 Foot high above the Water at the Place *m m* where the Piston work'd, and the Pump of *Fig.* 18, and 20 Foot high at *n n* where the Bucket work'd, moving from *n n* to *m m*, he reason'd thus: If Nature abhors a Vacuum, since the Space under the Bucket in the Pump of *Fig.* 18. is 72 times greater than the Space under the Bucket in the Pump of *Fig.* 17. Nature will more easily fill up the little Vacuum and push up the Water to the Bucket of the Pump of *Fig.* 17. than that of *Fig.* 18. But finding the contrary to happen, the Water soon rising up to *m m* in the great Pump, and no higher than *n n* in the small high Pump tho' its Piston B was work'd ever so long; judg'd that the Water might be push'd up by the Pressure of the Air, which acted within a limited Height proportional to its Weight; and that there might exist a Place void of Air, such as that in the Tube of *Fig.* 17. between *m m* and *n n*. To confirm this, when Water was pour'd into the Tube of *Fig.* 17. up to the Height *n n* of 34 Feet above the Water in the Well, (in which Tube it was kept up by the lower Valve) and the Piston was thrust down to *n n* so as to touch the Water, then raised up to *m m*, no Water follow'd, but the Space between *n n* and *m m* was void both of Air and Water. Then considering that Mercury weighing between 13 and 14 times more than Water, a Column of that Fluid near 14 times shorter than a Column of Water of the same Diameter would weigh as much and be much more manageable, (an Height of 30 Inches of Mercury answering to $33\frac{1}{4}$ Feet of Water) he got a Glass Tube of about 40 Inches high and a Quarter of an Inch Bore, hermetically, or close, seal'd at one end and open at the other; and having fill'd it full of Mercury, stop'd the open End with his Finger till he inverted it into a Vessel of stagnant

ſtagnant Mercury, when withdrawing his Finger under the Surface of the Mercury in the Veſſel from the Bottom of the Tube, he permitted the Mercury in the Tube to communicate with the ſtagnant Mercury in the Veſſel, without ſuffering any Air to go up into the Tube, (which in that caſe would be viſible enough) and perceiv'd the Mercury to quit the Top of the Tube, and immediately to come down and reſt at the Height of 30 Inches, leaving the Top of the Tube quite void of Air. *N. B. To ſhew there was abſolutely no Air in that Space, upon inclining the Tube the Mercury would riſe up and ſtrike againſt the Top of the Tube, and quite fill up the Space, which it always left empty upon ſetting the Tube upright again.* Lect. X.

3. *Toricelli* made this Experiment in the Year 1643, and ſent an Account of it to *France*, to Father *Merſennus*, who made it publick. Monſieur *Paſcal* made many fine Experiments with this *Toricellian* Tube upon a Mountain 400 Fathom high at *Clermont* in *Auvergne*, eſpecially thoſe three remarkable ones. The firſt in a Garden at *Clermont*, where the Mercury ſtood at 26 Inches 3 Lines * (*French* Meaſure); the ſecond about the third Part of the Way up the Mountain, where it ſtood at 25 Inches, having fallen 15½ Lines in that Height; and the 3d at the Top of the Mountain where the Mercury ſtood at 23 Inches and 2 Lines, being fallen in the whole 3 Inches and 1½ Line. It was not till the Year 1645, or 1646, that the *Toricellian* Tube became a *Barometer* or *Baroſcope*, that is, till *Toricelli* obſerv'd that the Tube being left ſtanding in the ſtagnant Mercury in the Baſon, would be ſometimes higher and ſometimes lower in the Tube; and therefore that not only the Preſſure of the Air kept up the Mercury in the Tube, but that the Preſſure of the Air was ſometimes greater and ſometimes leſs: and therefore that this Inſtrument wou'd be a certain Meaſure of the different Preſſure of the Air, for which reaſon he call'd it a *Barometer* or *Baroſcope*. He begun then alſo to obſerve, that in fair Weather, or a little before it, the Mercury would riſe in the Tube; whereas it wou'd fall in ſtormy or rainy Weather, or a little before. Hence it is that we call this Inſtrument a Weather-Glaſs. There are ſeveral Sorts of Weather-Glaſſes; but before I come to deſcribe them, and ſhew which I think the beſt, I ſhall recapitulate in reſpect of the Air, either ſpeaking of ſome Properties of it that I have omitted, proving ſome that I have only hinted at, and illuſtrating by further Experiments others that I have already prov'd.

4. Tho' the Air is inviſible, That it is a Body, is plainly ſeen from the Reſiſtance that it makes to Bodies moving in it: and That it is a fluid Body, appears from its yielding to any Force impreſs'd.

* As we have ſaid before, a *Line* is the 12th Part of an Inch.

Lect. X.

BY the Experiment of weighing a certain Quantity of Air in a Copper Ball *, it appears that the Air is heavy, and as all heavy Bodies tend to the Center of the Earth, the whole Air muſt tend that way, and preſs upon Bodies under it.

* L. 7. N° 3.

EXPERIMENT 1. *Plate* 21. *Fig.* 1.

Plate 21. Fig. 1.

SEVERAL ways of making the *Toricellian* Experiment ſhew it. See *Plate* 21. *Fig.* 1. The 3 Tubes F G, C M, and *n a*, open at Bottom and hermetically ſeal'd at Top ſtand in the ſtagnant Mercury in the Diſh G E, while the Mercury in the ſaid Tubes ſtands at A, C, and *a*, at the ſame Height in the horizontal Line A *b*; therefore ſince Fluids preſs according to their perpendicular Height †, the Parts of the Surface of the Mercury G E at G *m* and *n*, are equally preſs'd by the Mercury in the Tubes. I ſay, all the reſt of the Surface muſt be preſs'd proportionably by the Air, each Part of that Surface which is as big as the Section of any of the Tubes being preſs'd by a Column of Air of the ſame Diameter reaching up the whole Height of the Atmoſphere, and weighing as much as any of the Columns of Mercury, which we have ſuppos'd of the ſame Diameter. And this muſt be, otherwiſe the *Surface of Fluids* would not *be preſs'd in all its Parts alike*, as we have demonſtrated ‖.

† L. 7. N° 10.

‖ L. 7. N° 8.

To ſhew that if the Column of Mercury F G had not preſs'd upon the Surface G E at G, the Air would have preſs'd there; break off the Top of the Tube at F (where it is drawn ſmall) and immediately all the Mercury will fall down, the Air coming to preſs inſtead of it; there being no need for the Column of Mercury G A to preſs upon G, when the Air can come at it to preſs it as much as the other Parts of the Surface of the ſtagnant Mercury are preſs'd.

EXPERIMENT 2. *Plate* 21. *Fig.* 2.

Plate 21. Fig. 2.

5. TAKE ſuch a Veſſel as D, cylindrick all the way except at the Top, which is drawn out into a ſmall Point, and having fill'd it with Water by laying it down in a large Veſſel as W, hold it upright and raiſe it up till its Mouth be but a little under Water, and it will continue full; which ſhews that the Preſſure of the Air on the ſtagnant Water W keeps up the Water in the tall Veſſel C D. To confirm this, break off the Point at D, and the whole Water will fall down as ſoon as the Air can preſs downwards in its ſtead to balance the Preſſure of the Air on the other Parts of the Surface W, which the Water did before.

THO' the Column of Mercury or of Water that preſſes upon Part of the Surface of the ſtagnant Liquor in the Veſſel below be not equal in Weight to a Column of the Atmoſphere of the ſame Baſe, yet the Preſ-

front. p. 252.

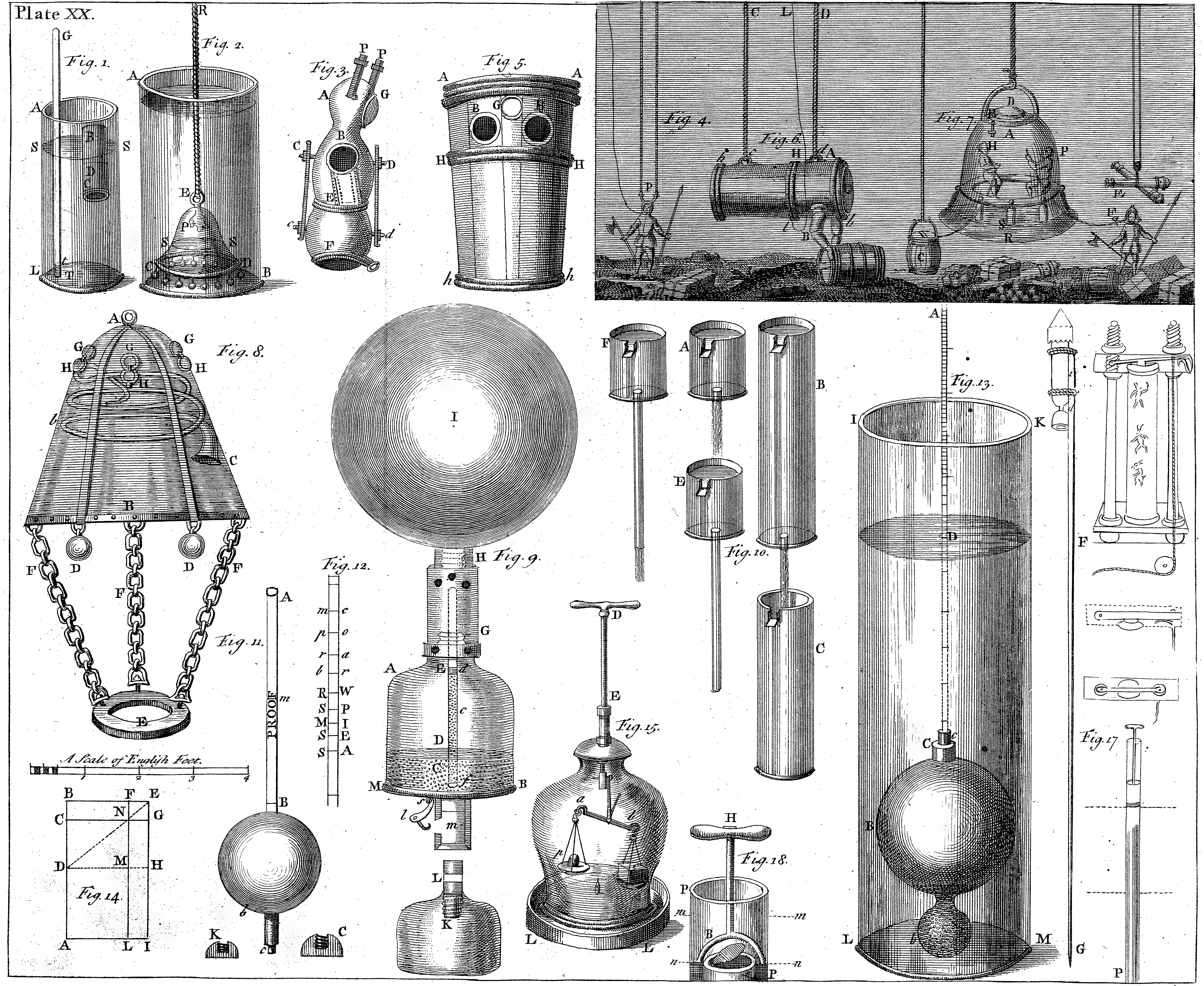
Plate XX.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 17.
Fig. 18.
PROOF
A Scale of English Feet.
1
2
3
4
J. Mynde sc.

ſure is the ſame; becauſe what is wanting in the Preſſure of other Fluids Lect. X. is made out by the Preſſure of Air at the top of the Tubes or upright Plate 21. Veſſels which contain them. Thus when the End A of the *Toricellian* Fig. 8. Tube in *Fig.* 1. is brought down to *f* below the Level of A *b*, it is plain that the inclin'd Column of Mercury that it contains being of a leſs perpendicular Height than A G, does not preſs ſo much at *n* as the Column *a n*; but then the Air that preſſes on the Top of the Tube at *f* makes up that Deficiency. Thus alſo the Preſſure of the Air on the Top of the Veſſel D C (*Fig.* 2.) made up for the want of an Height of 34 Foot of Water at W: as it appear'd when the Air ruſh'd in upon breaking open D. But this will be better illuſtrated by the following

Experiment 3. *Plate* 21. *Fig.* 3.

6. Having cemented the Tube D E open at E and hermetically Plate 21. Fig. 3. ſeal'd at D into the Piece of Wood D, in order to hang it up to one of the Scales of the Balance A B, put a Weight in the oppoſite Scale to keep it *in æquilibrio*; and that Weight will be only equal to the Tube D E, becauſe as much as a Column of Air preſſes it down at Top, juſt as much does an oppoſite Column of Air puſh it up on the Inſide. But if you fill the Tube with Mercury, and invert its open End in a Diſh of Mercury V (ſo as to make the *Toricellian* Experiment of it) it will require as much more Weight in the oppoſite Scale to make an Æquilibrium, as the Weight of all the Mercury in the Tube. Now it is plain that in this laſt Experiment you don't weigh the Mercury, becauſe it don't cohere to the Sides of the Tube ſufficiently for that; but you weigh the Column of Air that preſſes at top of the Tube at D, which Column you did not weigh in the firſt Experiment, becauſe it was counterbalanc'd by another Column of Air puſhing upwards into the Tube, but which is now employ'd in ſuſtaining the Mercury in the Tube; or rather excluded by the Column of Mercury which neceſſarily preſſes the middle of the ſtagnant Mercury at V.

That the Mercury in the Barometer or *Toricellian* Tube cannot be kept up without the Preſſure of the Air, and is kept up juſt in proportion to that, has been ſhewn ſome Years ſince by a very pretty Experiment contriv'd by the ingenious Mr. *Auzout* in the following manner.

Experiment 4. *Plate* 21. *Fig.* 4, & 5.

7. *a* A B is a kind of Cupping-Glaſs with a Braſs Head and Female Plate 21. Fig. 4, 5. Screw in its Neck, to receive upon occaſion the Male Screw of the Braſs Ferril fix'd on near the open End of a Barometer Tube *c* B C. The large End or Mouth of the Cupping-Glaſs has a Braſs Cover or Plate cemented

Lect. X. Plate 21. Fig. 4.

cemented to it with a Female Screw thro' it about the mid-way between the Edge and Center of the Plate, in order to receive a Brass Male Screw cemented near the End of another Tube D*d*, of a small Bore and about 33 Inches long. This must be so contriv'd, that when the Ends of these two Tubes are fix'd to the Cupping-Glass, by means of their small Screws, their Ends that go in to the Cupping-Glass shall pass beyond each other without touching; for which purpose the Cupping-Glass must not be less than of 2 Inches in its inward Diameter, and as much in Height. Having filled the Tube *c*BC quite full of Mercury, screw on the Cupping-Glass to it, as in *Fig.* 4. Then thro' the Hole *a* fill the Cupping-Glass also with Mercury: screw in the Tube D*d*, and fill that Tube likewise with Mercury. Then setting your Finger against D, invert the whole Machine into the Dish of stagnant Mercury DM (*Fig.* 5.) and taking away your Finger from D, all the Mercury will descend out of the Tube *c*BN, and out of the Cupping-Glass as low as the Top of the Tube *d*D, but not so low as the Hole *c* of the Tube *c*BN; and likewise down to the Line *m m* in the Tube *d*D, being the Barometrical Height, *viz.* 29 or 30 Inches. Now if with a Key applied at B, you unscrew gently a little way the Tube *c*BC, the Air will insinuate between the Threads of the Screw into the Vacuum in the upper Part of the Cupping-Glass and push the Mercury A*dc* up to *nn*, the Barometrical Height in the Tube *c*BN, whilst the Mercury falls quite down from *m m* in the Tube *d*D to the rest of the stagnant Mercury at DM. Here the Pressure of the Air on the Surface DM sustained the Column of Mercury D*m m*, when no Air cou'd come in at top and there was a Vacuum at *c d*. And whilst that Vacuum continued, no Mercury remain'd in the Tube *c*BC, till by opening the Screw at B the external Air came in and press'd up the Mercury to *n n*, that the Surface *c d* might be equally press'd in all its Parts, *viz.* by the Column of Mercury at *c*, and by the Air every where else: and that the Surface DM in the Dish below shou'd likewise be press'd alike in all its Parts, the Part at D (being now doubly press'd, that is by the Column of Mercury and the Air that was come in above it) yielded to the Column of Mercury *m m* D, that came down thro' it, and became press'd by the Air that came down instead of the Mercury and press'd as much.

8. Since Air is a Fluid, it must press upwards as well as downwards, and sidewise, and in all manner of Directions, and that according to its Height *, or the Force that drives it; but as we have consider'd this already concerning other Fluids, we will here only shew that the lateral Pressure is equal to the perpendicular, and the rest will easily be granted.

* L. 7. N° 10.

Expe-

EXPERIMENT 5. *Plate* 21. *Fig.* 6.

TAKE a tall Glass Phial of about 9 or 10 Inches high, and having drill'd about 3 Inches from its Bottom at B, stop the Side-Hole and fill the Bottle thro' the Neck: the Bottle being fill'd, thrust into it a Glass Tube EF, a Foot long, and open at each end, so that its End may come down lower than the Hole B. You must stop close the Neck at P with Wax or Pitch, which you have beforehand stuck to the Tube round about, so that no Air may come into the Phial between the Neck and the Tube. Then the Tube being fill'd with Water as well as the Phial, when you open the Hole B the Water runs in part out of the Tube, but it stops at A at the Height of the Hole B, and the whole Phial remains full. Now if the perpendicular Pressure of the Air was greater than the lateral, all the Water wou'd have been push'd out of the Tube EF, and wou'd not fail to run out; but as this does not happen here, it is plain, that the Air presses laterally with so much Force against the Hole B, that the Water cannot run out of the Phial, there being only the Water EA which runs out of the Tube, whilst FA remains full up to the Height of the Hole. Plate 21. Fig 6.

9. THE Pressure of the Air is also shewn by many Experiments on the Air-Pump; but I shall not mention them till I come to speak more particularly of that Machine. We shall only consider now how great is the Quantity of Pressure on a Man's Body.

10. SINCE Fluids press in all manner of Directions, the Pressure of the Air on a Man's Skin taken off and laid horizontally wou'd be just the same as it is upon the Skin now that it infolds the Body and Limbs: therefore only knowing how many square Inches any Man's Skin contains, we may by allowing the Weight of a square Column of Mercury, whose Height is such as it stands in the Barometer, for the Pressure upon each Inch, easily estimate the whole. For example, if we allow 15 square Feet for the Skin of a middle-siz'd Man, then it will contain ($15 \times 144 =$) 2160 Inches. Now the Weight of a Cubic Inch of Mercury is 8,101, *&c.* Ounces Avoirdupoids, and the Barometer in *England* stands at 30 Inches and $\frac{8}{10}$ when highest, at 28 Inches when lowest, and therefore at 29,4 Inches at a Mean. Consequently when the Air is lightest it will weigh 14 Pounds 2 Ounces Avoirdupoids, *&c.* upon a square Inch; when at a Mean 14 Pounds 14 Ounces, upon the same Surface; and 15 Pounds 9 Ounces, when the Air is heaviest: from which it follows, that in fair Weather, when the Air is heaviest, a middle-siz'd Man carries a Weight of Air equal to 33684 Pounds, eight Ounces Avoirdupoids; when it is foul or windy, and the Air is lightest, a Weight of 30622 Pounds five

Lect. X. five Ounces; and 32153 Pounds six Ounces at a Mean *. What enables a Man to bear this great Weight, is the Air included in our Flesh and the Cavities of our Bodies, which acts by its Spring against the Pressure of the external Air. And this leads me to the Consideration of the Air's Elasticity.

* Annot. 1.

† L. 7. N° 21.

10. We have already explained what the Air's Elasticity is †, and shew'd by the 21st Experiment of Sect 7. *Plate* 10. *Fig.* 11. that the Density of the Air, when compress'd, is proportional to the Weight that compresses it; and will return to its natural State when that Weight is remov'd. But this Expression *natural State* must be understood of the Density the Air has before it is compress'd by the Experiment we are making, or rather *farther compress'd*; for the Air that we breathe near the Earth is already in a compress'd State, as it is condens'd by the Weight of the superior Air, and therefore will rarify it self as some of the superincumbent Weight is taken off, either by some of the superior Air being blown off, or by removing the Air that you examine, farther from the Earth upwards: and this Dilatation increases as the Pressure diminishes; as may be gather'd from Mr. *Pascal*'s Experiments, and those of many other Persons, who have carried Barometers up to the Top of Mountains, and have found the Mercury to descend as they went up, and to rise again as they came down.

11. If the Air was every where of the same Density ‡, it would be an easy thing to find the Height of the Atmosphere thus. Make the *Torricellian* Experiment at the Bottom of a Mountain, and observe the Height at which the Mercury stands in the Tube, suppose at 30 Inches: then make the Experiment again at the Top of the Mountain (which we will suppose for example 1015 Foot high) and observe what is the Height of the Mercury in the Tube there, suppose 29 Inches; then the Height of the Atmosphere wou'd be found by this Analogy:

As the Difference between the Height of the Mercury at the Top, and the Height of it at the Bottom of the Mountain, which is here one Inch :

To the Height of the Mercury at the Bottom of the Mountain, which is here 30 Inches ::

So is the Height of the Mountain, here 1015 Foot:

To the Height of the Atmosphere, *viz.* 30045 Foot, or five *English* Miles and five Furlongs.

But the Air is not every where of the same Density, as we have said before; and he that goes up a high Tower or a Mountain with a portable Barometer

‡ It is well for us that the Air varies in Density; for otherwise we never shou'd have any Rain, and be liable to so many other Inconveniencies, too long to mention here, that few Animals could live in it.

Barometer may obſerve, that if the Mercury falls $\frac{1}{10}$ of an Inch at the firſt 90 Feet of Riſe, it will not fall the next tenth of an Inch, till the Barometer is carried up 93 Feet higher: and ſo the Height of every Column of Air of the Weight of $\frac{1}{10}$ of an Inch of Mercury will vary according to the Height of its Situation in the Atmoſphere, each being about three Feet longer than the laſt, tho' containing no more Air. And if for an Height of 1015 Feet the Mercury falls an Inch, the numbers of Feet expreſſing the Height of the Columns from the Ground upwards, will be 90, 93, 96, 99, 102, 105, 108, 111, 114, 117. Lect. X.

It is from ſuch kind of Obſervations that Dr. *Halley* and others have made Tables, to ſhew what would be the Heights of the Mercury in the Tube, and the Denſity of the Air at different Heights from the Earth. Here follow two of them from Dr. *Halley*.

I.

A TABLE, *ſhewing the Altitude to given Heights of the* Mercury.

Inches.		Feet.
30		0
29		915
28		1862
27		2844
26		3863
25		4922
20		10947
15		18715
10		29662
5		48378
1		91831
0.5		110547
0.25		129262
0.1	29 Miles, or	154000
0.001	41 Miles, or	216169
	53 Miles, or	278338

II.

A TABLE, *ſhewing the Heights of the* Mercury, *at given Altitudes.*

Feet.	Inches and Tenths.
0	30.00
1000	28.91
2000	27.86
3000	26.85
4000	25.87
5000	24.93
1 Mile.	24.67
2	20.29
3	16.68
4	13.72
5	11.28
10	4.24
20	1.60
25	0.95
30	0.23
40	0.08
	0.012

N. B. Tho' theſe Tables don't perfectly agree with Phænomena, for want of a ſufficient number of Obſervations to build them upon; ſince they are the beſt extant, I was willing to give them. When more accurate Experiments are made with a very good portable Barometer on the Tops, Bottoms, and Sides of Mountains on the ſame Days, they will afford Materials for better Tables.

Lect. X.

12. Tho' we have in our seventh Lecture, and its Notes, explain'd the decreasing Density of the Air; to set the matter still in a clearer light, we will describe an Experiment, which, tho' it cannot be made, may be suppos'd for a further Illustration.

* Plate 21. Fig. 7. Let us suppose A B * to be an horizontal Tube 60 Miles long, close at one End as at A, and that A C is one tenth Part of he whole Tube fill'd with common Air, and that that Air is kept in by a Piston at C, and that the Parts *d e*, *e f*, *f g*, *g h*, *h i*, *i k*, *k l*, *l m*, *m n*, are quite empty of Air, which is hinder'd from coming into the Tube by a Stopple at B. Now if we suppose this Tube set upright on its End A, at *a*, the Stopple B taken out at *b*, and the Piston C at liberty to move freely, that Piston will rise up to *c*, and by the Elasticity of the Air check'd by its Pressure, the equal Portion of Air 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, will expand so as to fill all the Tube, but into unequal Spaces, according as they are press'd with more, or less, or no superiour Air: comparing this with what has been said in Lect. 7. N° 23. and Annotations 9 and 10. L. 7. Ann. 9, 10.

13. We generally measure the Height of the Mercury in the Barometer from the Level of the Sea, to which we reduce all Observations, if we would be accurate; otherwise it is not understood by others at what Height the Mercury really stands in our Barometer, if we only mention at what Division its Surface is in our Scale, unless we say how high our Instrument is placed above the Sea.

14. If we should carry a portable Barometer into a Coal-Pit, the Mercury would rise in the Tube, in proportion to the lengthen'd Column of Air pressing upon the Mercury in the Cistern. To shew this, we may use Water instead of Air, as in the following

Experiment 5. *Plate* 21. *Fig.* 8.

Plate 21. Fig. 8. Having inverted the *Toricellian* Tube as usual, in the Vessel M, with the Mercury standing in the Tube at *m m*, fasten three Strings like T H to the Top of the Vessel M, and by those Strings, and the Hook H, let down the Barometer into the Water of the Jar A B C D, 14 Inches below the Surface S *s*, and you will find that the Mercury in the Tube will rise from *m m* to *n n*, because as Water weighs 850 times more than Air, a Column of Water of 14 Inches, weighs as much as a Column of Air of the same Diameter, 991 Feet, and eight Inches high, which might be added to the Column pressing on the stagnant Mercury above the Level of the Sea. As you take out the Barometer, the Mercury falls.

15.

15. We have shewn how the Air's * Elasticity exerts itself, when it is compress'd into a less Space than what it usually possesses near the Earth, by other Bodies, Fluids or Solids, made use of to compress it †: Now we will shew how its Elasticity dilates it, when it is less compress'd than it is in its common State in which we breathe it, by easing it of some of the Weights that keep it in that Condition. * L. 7. † L. 7.

The Air therefore, such as it is near our Globe, rarefies itself in such a manner, that *its Bulk is always in an inverse Ratio of the Weights that compress it.* Mr. *Boyle* and Monf. *Mariotte* have settled this Rule by the following Experiment.

Experiment 6.

Take a Barometer Tube A B, (*Plate* 21. *Fig.* 9.) which, having been well fill'd, will hold the Mercury suspended at the Height C B. If you let in to this Tube as much Air as would fill in it the Space A D, the Mercury will not stop at the Height B D; but will fall, and stop at a certain Height B E, because the Air which is in A D rarefies itself, and fills A E. By help of this Experiment, which justly measures the Spaces A D, E D, and the Heights B C, B E, the foregoing Rule has been establish'd, by reasoning in the following manner. The Force with which the Air is naturally compress'd here, is equal to the Weight of the Atmosphere: the Mercury which stands at the Height B C, is by its Weight *in æquilibrio* with the Weight of the Atmosphere, and therefore that Weight may be express'd by the Column of Mercury B C. Plate 21. Fig. 9.

The Air introduced into the Tube, and which took up the Part of it A D, was compress'd by that Weight: but when, after the Experiment was made, its Bulk is by Rarefaction become greater, so as to make it take up the Space A E; consequently the Elasticity which this rarefied Air has left, join'd to the Weight of the Column of Mercury E B, is *in æquilibrio* with the Weight of the Atmosphere, which presses on the stagnant Mercury at B, or with the Column of Mercury C B. Now if from those two Sums you take away the Column of Mercury E B, which is common to them, there remains the elastick Power of the Air at A B, which is *in æquilibrio* with the Weight of the Column of Mercury E C; thus the Weight which compresses the rarefied Air A E, is equal to the Weight of the Mercury at C E. If there-

 fore

* The Elasticity of solid Bodies is very different from the Elasticity of the Air; for they dilate themselves quite otherwise. For when Air ceases to be compress'd, it not only dilates itself, but it takes up a greater Space, and appears under a greater Bulk than before, which does not happen to solid Bodies that are elastick, which only recover the Figure that they had before they were compress'd.

Lect. X. fore you meaſure the Lengths A D, A E, which the Air occupies in both Caſes, you will find them to be, as C E to C B; and conſequently the Bulks of Air are in an inverſe Ratio of the Weights, which compreſs them.

When you would make this Experiment, you muſt make uſe of a thick Tube, but of a ſmall Bore, and all the way exactly of the ſame Bore, which you muſt try firſt by meaſuring it with Mercury. Then you muſt fit into A (which End of the Tube muſt be open) a Glaſs Stopple ſo tight as to hinder the Air from coming in at that End: By moving this Stopple, you may let in juſt as much Air above the Mercury as you would have. If you ſhould make uſe of a Tube hermetically ſeal'd at Top, in order to let in the Air at Bottom after having pour'd in the Mercury; and that you invert it afterwards, in order to make the Mercury come down, there always remains a great deal of Air diſpers'd here and there between the Parts of the Mercury, which does not riſe up thro' the Mercury, ſo that one can never exactly meaſure the Place, that the Air muſt occupy at the Top of the Tube; and conſequently not be certain of the Truth of what has been aſſerted here. This Inconveniency is remedied, by letting in the Air at Top, and then keeping the Entrance ſhut with the Glaſs Stopple. *N. B.* This is treated Algebraically in the Notes *.

* Ann. 2.

You are not to think that for theſe Experiments there is a Neceſſity of making uſe of a Tube, whoſe Length is greater than the Height of the Mercury in the Barometer: For the thing may be done with much ſhorter Tubes; nay Tubes of any Length, provided your Reaſonings be upon the ſame Foundations. Let us ſuppoſe a Tube but 6 Inches long, that you would fill with Mercury, and in which you wou'd leave ſuch a Quantity of Air, that there ſhall be only two Inches of Mercury left when the Tube is inverted: This being fixed, it is required to know how much Air you muſt then leave in the Tube? I ſuppoſe that the Mercury in the common Barometer ſtands then at 29 Inches, the Difference between that Height, and the Height required, will be then of 20 Inches, the Space that the Air muſt take up in the Tube, after the Experiment is of 4 Inches, and conſequently you'll have this Analogy 29 : 27 : : 4 : $3\frac{21}{29}$; wherefore there muſt be $3\frac{21}{29}$ Inches of natural Air left in the Tube, if you would have the Mercury afterwards preſerve an Height of 2 Inches.

16. How far this Property of the Air of expanding it ſelf is extended, we do not certainly know; and it is very probable that it can be determined by no Experiments. Neverthleſs, if you compare the following Experiments

riments with the Experiment of the Air compared in a Pump or Syringe, it will appear that the Air may take up twenty thousand times more Space in one Case than in the other. Lect. X.

EXPERIMENT 7. *Plate* 21. *Fig.* 10.

LET the Glass A B, about 14 Inches high, be exactly fill'd with Water; it has a Brass Cap fix'd to it at the End B, by which it is to be screw'd to the Brass Pump or Syringe, that is represented in *Plate* 21. *Fig.* 11. By drawing out the Piston of the Pump, the Water descends into it by its Gravity; and the Place in the upper Part of the Vessel is void both of Air and Water. The Air-Bubbles in the Water, which are now compressed, because the Air does not act upon the Surface of the Water, expand themselves, and rise up to the Surface of the Water; in that Motion the Bubbles are accelerated, so as not to be seen distinctly near the Surface, upon account of their very swift Motion; they also grow bigger as they ascend, and if you compare the Diameter of a Bubble at B, with its Diameter, when it is come almost up to the Surface of the Water, but so far from it as to be seen distinctly, its Diameter is at least four times as great as before. Plate 21. Fig. 10.

THE upper Part of the Glass, as was said before, is intirely void of Air, for the small Quantity of Air, which is continually going out of the Water, is not to be taken notice of here; therefore the Air-Bubbles near B, which is about a Foot below the Surface of the Water, are compressed only by the super-incumbent Water; which Pressure is to the Pressure of the Atmosphere nearly as 1 to 32; in which Ratio also is the Space taken up by the Air, when it is compressed by the whole Atmosphere, to the Space taken up in the Bubbles above-mentioned; their Diameter in their Ascent, as has been said before, becomes quadruple; that is, the Bubble becomes 64 times bigger than it was; and so the Space taken up by the Air in this last Case, is to this Space taken up by the Air, when compressed by the Atmosphere, as 64 times 32 (that is, 2048) to 1. The Air compressed by the Atmosphere is reduc'd to a Space 10 times less in the Forcing-Pump, and so the Density of the Air above-mention'd is to the Density of this Air, as 1 to 20480. Extracting the Cube Roots of these Numbers, we shall find that the Distances between the Centers of the Particles, in these two Cases, are as 1 to 27.

17. HENCE we conclude, that the Particles of the Air are not of the same Nature with other elastic Bodies, for the single Particles cannot expand themselves every way into 27 times the Space, and so be increased 2000 times, preserving their Surface free from every Inequality or Angle; for

Lect. X. for in every Expanſion or Compreſſion, the Parts are eaſily moved, one amongſt another; but as the Air may be dilated much more than in this Experiment, it follows, that *the Air conſiſts of Particles which do not touch one another, and that repel each other*; as we have ſaid in the Beginning of this Book, and ſhall ſhew further in our ſecond Diſſertation about the Riſe of Vapours; and we have ſhewn, that in ſeveral Caſes there are Particles endowed with ſuch a Property; and it is plain enough that it obtains here; but we are entirely ignorant of the Cauſe of this Force, and it muſt be looked upon as a Law of Nature, as is plain from what has been ſaid.

Plate 21. Fig. 12.

18. The Force, by which the Particles of the Air fly from each other, increaſes in the ſame Ratio as the Diſtance in which the Centers of the Particles are diminiſhed; that is, that Force is inverſely as this Diſtance. To demonſtrate which, let us conſider two equal Cubes A and B, (*Plate* 21. *Fig.* 12.) containing unequal Quantities of Air; let the Diſtances between the Centers of the Particles be as 2 to 1, the Numbers of the Particles will be in the ſame, but inverſe, Ratio in the Lines *d e* and *h i*; the Numbers of the Particles acting upon the Surfaces *d g* and *h m* are as 1 to 4; namely, as the Squares of the Numbers of the Particles in equal Lines, and as the Cubes of thoſe Numbers; that is, as 1 to 8, ſo are the Quantities of Air contain'd in the Cubes; in which Ratio alſo are the Forces compreſſing the Air in the Cubes*. The Forces acting upon the equal Surfaces *d g* and *h m*, are as the Forces by which the Air is compreſſed; they are alſo in a Ratio compounded of the Numbers of the Particles acting, and the Action of the ſingle Particles; therefore this compounded Ratio is the Ratio of 1 to 8: The firſt of the compounding Ratio's, as has been ſaid, is, that of 1 to 4; wherefore, neceſſarily the ſecond is that of 1 to 2, which is the inverſe Ratio of the Diſtances of the Particles. And this Demonſtration is general; for by 1 and 8 we expreſs the Cube Roots; and laſtly, by 1 and 2, the Roots of thoſe Cubes.

* Plate 21. Fig. 12. L. 8.

But now to return to the Barometer. Since all the Variation of the Height of the Mercury in the Barometer is but of three Inches in perpendicular, ſeveral Philoſophers have endeavour'd to render this Variation more ſenſible by many Contrivances, a few of which I will deſcribe here, with Obſervations upon them.

* Plate. 21. Fig. 1.

First, Sir *Samuel Moreland* contriv'd an inclin'd Tube, as F D C*. For if in the ſame Veſſel of ſtagnant Mercury be ſet the upright Tube G B A, with the ſaid Tube, and the Height B G be of 28 Inches, and G A 31 Inches, and thro' B and A two Lines be drawn parallel to the Horizon,

Horizon, then as the Mercury rises in the Tube G A from B to A, it will also rise in the bent Tube from D to C. By means of this Bend, or Inclination of the upper Part of the Tube, the Length D C may be as you think fit, so as to be, for example, twice, three, or four times greater than B A, so as to make the Rise of the Mercury so much more sensible in D C than B A. This appears to be a fine Invention, but it has its Inconveniencies: for the Surface of the Mercury in the Tube D C is not parallel to the Horizon, as may be seen in *Fig.* 13. which represents the End of the inclin'd Tube D C, at *f g*: but it is convex, as *k h g*. Here the Question may be ask'd, where must we reckon the true Height of the Mercury? Must we fix it at *k*, or *h*, or at *g*. Besides, as the inward Surface of the Tube is a little rough, it hinders the Mercury from descending at the under Side *g m*, since it is carried down by so weak a Weight, as hardly to be able to overcome the Friction, so that at first we do not see the true Descent. This is a considerable Inconveniency, when the Tube D C is much inclin'd; and if it is not very much inclin'd, the Advantage of the large Divisions is lost. It appears hereby, that this Contrivance is more ingenious than happy, and that one may almost as soon trust a common Barometer. Tho' I have never seen any of these Instruments, where the Mercury was not apt to stop often beyond, or short of its true Place; yet I have heard that Mr. *Orme*, of *Ashby de la Zouch* in *Leicestershire* *, has a particular Method of preparing his Quicksilver, so that it shall not stick by the way, or part as it descends.

Lect. X.

Plate 20. Fig. 1.

Plate 21. Fig. 13.

* Ann. 3.

19. THE 14th Figure represents Dr. *Robert Hooke*'s Wheel-Barometer. A B D G R F is a Tube bent at Bottom near R G F, and which has a great Ball A B at top. On the Surface of the Mercury near G, there is a Ball, or a little Cylinder of Iron suspended by a Thread F S D H, which goes round a small Pulley S D, which it causes to turn. At the other end of the Thread near H is fasten'd another Ball lighter than the former, which holds the Thread stretch'd. The Pulley has upon its Axis a long Index L K, which shews the Variations of the Heights of the Mercury in the Barometer upon a large graduated Circle M N P O. When the Mercury stands at the Height of 31 Inches in the Tube of the common Barometer, it stands in this Barometer at the Height A B, and in the lower End near G, so that the Column suppos'd to be continu'd from G to A will be 31 Inches long. But if the Mercury sinks in the common Barometer to 28 Inches, it will sink in this Barometer from A to Z, and rise in the turn'd up End from G to F, till the Column F Z be but 28 Inches long. Consequently, if the Tube was every where of the

Plate 21. Fig. 14.

Lect. X. the same Diameter, the Mercury at top near A B coming to fall 1 $\frac{1}{2}$ Inch, would make that which is at bottom rise from G to F, also one Inch and $\frac{1}{2}$, which would make the Column F Z three Inches shorter than the Column G A, and consequently the Motion of the Mercury in this Barometer would be half less than in the common Barometer. But as the Tube here has at its Top the Globe A B of a large Diameter, a small Descent of Mercury in this Globe will supply enough to cause a Rise of three Inches in the Tube F G; and thereby the whole Variation of the Heights of the Mercury of the common Barometer is supplied to this Barometer. Now let us suppose the whole Circumference of the Pulley S D to be of three Inches, then it will make one Turn, while the Mercury of the Tube G F, by its rising, will raise up the Iron Ball upon its Surface three Inches: and so the Hand L K will with its small End describe the whole Circle L M D O N L. If the Diameter of this Circle is of one Foot, the Motion of the Mercury in this Barometer will appear to be of more than three Feet. This Barometer shews the considerable Variations of the Height of the Mercury very well; but when the Mercury first begins to rise or fall in the Tube G F with a small Convexity, or a small Concavity, the little Iron Ball has not Motion enough to cause the Pulley S D to begin to turn, because it cannot be without some Friction upon its Axis, which hinders one from seeing the small Variations of the Mercury; but when the Pulley begins to move, its Motion is greater than it ought to be at that time. This is doubtless an Inconveniency not easily to be remedied. This Barometer is also liable to many other Inconveniencies, which have been taken notice of in the *Philosoph. Transact.* N° 185. and therefore we may look upon it as of no use.

Plate 21. Fig. 14.

Plate 21. Fig. 15.

20. In the Year 1672 Mr. *Huygens* invented two Sorts of Barometers, of which I shall only describe the best here. The Tube O M P is 25 $\frac{1}{2}$ Inches long, and turn'd up at Bottom near M P: to each End of this Tube is fasten'd a Glass Cylinder O H, P C, 1 $\frac{1}{2}$ Inch high, and whose Diameter is 10 times greater than that of the Tube; from the middle of the lower Cylinder P C rises another Tube C N. I shall say nothing here of the way that this Barometer is to be fill'd, because it may be learn'd in the Description that Mr. *Huygens* gives of it. Let us then suppose the upper Cylinder to be fill'd with Mercury up to K, and the lower up to L, then the true Height of the Column of Mercury would be V K. If the Mercury sinks an Inch from K to R in the upper Cylinder, it must rise an Inch in the lower Cylinder from L to S, and then the true Height of the Mercurial Column will be I R; that is, two Inches shorter than K V: so that if the common Barometer has a Variation

tion of two Inches, this will have only half of that Variation, *viz.* one Inch. But the lower Cylinder muſt be fill'd with Water from L to C: if then the Mercury ſhould ſink in the upper Cylinder from K to R, and riſe in the lower Cylinder from L to S, the Water of the Cylinder P C would preſs upwards. Now if the Water was without Weight, it muſt riſe in the Tube C N 100 Inches, ſince the Bore of the Cylinder P C is 100 times greater than that of the Tube, ſuppoſing its Diameter as 10 to 1. But Water is heavy, its ſpecifick Gravity being to that of Mercury as 1 to 14; and therefore 14 Inches of Water from L to G will preſs upon the Mercury L L with as much Force as one Inch of Mercury does at S L: therefore it does not ſignify whether the Mercury L L be compreſs'd by an Inch of Mercury S L, or by 14 Inches of Water G L; therefore one muſt begin to take the true Height of the Column at the Line of Points I S. Now let the Water be at G, when the Mercury ſtands at K. If the Water roſe in the Tube as high as N, and the Mercury ſhould ſink in the upper Cylinder down to R, riſing only to S in the lower, then the true Height of the Mercury would be I R — I M, ſuppoſing I M to be $\frac{1}{14}$ of S N, ſo that the true Height would be M R: Now we muſt determine the Proportion that there is between the Difference of the Heights of the Columns of Mercury I K, M R, which are conformable to the Heights of the Water at G and N. *See it done in a little Compaſs algebraically in the Notes* *. But here at length, for the ſake of thoſe who do not underſtand Algebra.

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Plate 21. Fig. 15.

* Ann. 4.

Let us ſuppoſe our Atmoſphere to have its leaſt Weight; for example, to weigh equally with 28 Inches of Mercury in the Tube of the common Barometer: let the Length of the Tube N C be of 28 Inches, and wholly fill'd with Water up to N; then the Weight of thoſe 28 Inches of Water will be equal to the Weight of two Inches of Mercury: therefore the Weight of the Atmoſphere, which acts upon N, compreſſing it, and which is equal to 28 Inches of Mercury, will, together with the Weight of the Water N C, make a Preſſure equal to 30 Inches of Mercury: ſo that the Height of the Mercury in the Cylinder H O, and in the Tube O M P, muſt be of 30 Inches above the Surface of the Mercury in the Cylinder C P.

In this Reaſoning I have ſuppos'd the Water which comes down in the Tube N C to take up no room in Height in the Cylinder C P, (which is true, when the Cavity of the Cylinder C P is infinitely greater than that of the Tube N C; and then the Water in the Tube N C muſt have a Motion of 28 Inches, when the Mercury in the common Barometer moves two Inches: the Water riſes ſo much the more in the Tube N C, as the Preſſure of the Atmoſphere is the leſs, and the Mercury falls

Lect. X. Plate 21. Fig. 15.

the more in the common Barometer: on the contrary, the Water deſcends in the Tube N C, when the Preſſure of the Atmoſphere increaſes, and the Mercury riſes in the Tube of the common Barometer; ſo that the Motions of the riſing and falling of the Water in the Tube N C, are juſt the reverſe of the Riſe and Fall of the Mercury in the Tube of the common Barometer.

WITHOUT making any more Suppoſitions, let the Water actually ſink, and paſs from the Tube N C into the Cylinder C P; when the Atmoſphere becomes heavier, the Water will take up ſome Space, and conſequently the Mercury will be preſs'd upwards from the Cylinder C P into the Cylinder H O; if the Water of the Tube ſhould puſh the Mercury from S to L L in the lower Cylinder, the Mercury muſt alſo run into the upper Cylinder, and riſe to an Height equal to S L; that is, if the Mercury had ſtopp'd before at the Height R R, it would then riſe up to the Height K K, whence it would happen, that the whole Height of the Column of Mercury, which was before R I, would in that caſe become K V: If then R I had been before of 30 Inches, K V would then be of a greater number of Inches, at leaſt of a more conſiderable Height, and would conſequently preſs downwards with more Force than before, and thus the Water will be a-new puſh'd from the Cylinder C P upwards into the Tube N C, till the Weight of the Water, join'd to that of the Atmoſphere, becomes *in æquilibrio* with the Preſſure of the Column K V; hence it comes to paſs, that the Fall and Riſe of the Water in the Tube N C will be ſo much the greater, as the Cylinders C P, H O, are of a larger Bore, in reſpect of the Tube N C. If the Cylinders were an hundred times larger than the Tube N C, and all the Water ſhould paſs from N C into the Cylinder C P, it would there make an Height of $\frac{28}{100}$ Inches, or $\frac{7}{25}$; thus the Mercury in deſcending as much from S to L in the Cylinder C P, and riſing from R to K in the upper Cylinder H O, would form a Column K V of $29\,\frac{14}{25}$ Inches, which could not happen if the Variation in the Motion of the Mercury was but of two Inches, unleſs it were of $2\,\frac{14}{25}$ Inches. Experience has taught, that the Variation of the Height of the Mercury is actually of $2\,\frac{14}{25}$, and even ſomething more; therefore it will be found, that the Variation of the Height of the Water in the Tube N C, muſt be at leaſt of 28 Inches.

WE have here ſuppos'd, that Water was pour'd into the Tube C N, but, as it would freeze in Winter, Mr. *Huygens* wanted to have it mixed with Spirit of Nitre, and ting'd with Vitriol, the better to ſee where it ſtood in the Tube. And as Water is liable to evaporate, he was for having a Drop of Oil of Almonds pour'd upon it. This Barometer ſhews

Mr.

Mr. *Huygens*'s great Genius and Penetration; but yet it is not made use of, because it cannot be made without much Pains and Trouble: besides, it is liable to some Inconveniencies; for the Drop of Oil, which must be pour'd in from above, sticks to the Side of the Tube, and occasions the Water, after having pass'd thro' it several times, to make the Tube opaque, by spreading it. But the greatest Inconveniency is the Action of Heat and Cold, which causes the Liquor in the inferior Cylinder L C S, and in the Tube C N, to be affected like the Liquor in the Ball and Tube of a Thermometer. For this Liquor being rarefied by Heat, and condens'd by Cold, it happens that the same Quantity of Water rising up to different Heights, is *in æquilibrio* with different Quantities of Mercury: and therefore if, upon this Barometer, you would exactly mark the true Height of the Mercury, you must have a Thermometer just by fill'd with the same Liquor, whose lower Cylinder contains as much as P C, with a Tube, whose Diameter is like that of C N: then the Rise or Fall of Liquor in this Thermometer must be substracted from, or added to the Rise or Fall of the Liquor in C N, the Tube of the Barometer; or, at last, there must be a very exact Scale graduated upon some other Thermometer, to compare with it the Elevation of the Liquor in the Barometer, in order to make proper Allowances for what we have taken notice of; and this has been done very exactly by some learned Men. Some People have since endeavour'd to make these Barometers more simple, filling them with Mercury and Spirit of Wine: Instead of the Cylinders C P and H O, they only take Balls made like Pears, to which the Tubes may be join'd more easily by the Glass-Blowers; but by this Make, one takes away all the Exactness which Mr. *Huygens* had chiefly regard to, and also multiplies its Errors, as well because the Spirit of Wine is continually evaporating out of the Tube N C, which is open, as because it is liable to great Evaporations from Heat and Cold: lastly, another Inconveniency is, that one cannot make an exact Scale for the Tube C N, because of the Figure of the Bodies H O, C P, which are like Pears in this last Construction.

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THE Variations of the Height of the Liquor in this Barometer certainly do not deserve the Pains that we are oblig'd to take to make it fit for Observations; and therefore other Philosophers have endeavour'd to make it useful by making Alterations in it. It is said, that Dr. *R. Hooke* was the first who had that Design in the Year 1668, and that Mr. *Hubin* in *France* communicated it to the Publick in 1673; and lastly, that the Description of it was given in the *Philos. Transactions*, N° 185. Mr. *De la Hire* had the same Design afterwards: and there is reason to think, that he did not know that any body had before him given a Description of

Lect. X. this new Instrument, which may easily happen; for it would be wrong to suspect this great Mathematician of being willing to ascribe to himself the Discoveries of another, and publish them as his own.

21. This new Barometer, or old one improv'd, was made in the following manner.

Plate 21. Fig. 16. They took three Cylinders or Boxes, O X, Z C, D Q, of the same Diameter and Height, two of which, O X, Z C, are fasten'd to the Tube O S Z, as in the former Barometer, but to the upper Tube C D is join'd a third Cylinder Q D. The Tube D C is of an indefinite Length, but yet it is so constructed, that the Square of the Diameter of the Tube D C must be to the Square of the Diameter of the Cylinder C Z, as the Height to which the Mercury can rise in the Cylinder C Z, is to the requir'd Height of the Tube C D. Let us suppose this Barometer to be duly fill'd with Mercury; that in the Cylinder O X the Mercury stands near A, and from thence fills all the Tube O S R, and is come into the lower Cylinder Z C, quite to B: You must pour down upon the Mercury Brandy colour'd with Cochineal, from B to the middle of the Tube near G; then pour on Oil of Turpentine from G into the Cylinder D Q up to K. Then when the Mercury goes down in the Cylinder O X from A to L, it must rise as much in the lower Cylinder from B to H, which makes the Brandy with the Oil of Turpentine rise as much, and go up into the Cylinder Q D, from K to N, so that there is then the same Height and Pressure as before upon the Mercury in the inferior Cylinder C Z, because B K = H N; consequently the Pressure, which acts upon the Mercury B, does not change, but always remain the same; so that here you have only a recurve Barometer, upon whose Mercury all Variation of Pressure depends only upon the Pressure of the Air. As this Variation in the common Barometer is equal to three Inches, in this Barometer it will be equal to $1\frac{1}{2}$ Inch; and the Mercury may rise in the Cylinder O X from A to P p, which is the Height of $\frac{3}{4}$ of an Inch, and sink from A to L, which is likewise $\frac{3}{4}$ of an Inch: therefore the Mercury will sink in the Cylinder Z C from B to R, which is $\frac{3}{4}$ of an Inch, and rise from B to H, which is also $\frac{3}{4}$ Inch, and there will be in the upper Cylinder D Q Variations of the same Dimensions. Now let us suppose the Diameter of the Tube C D to be of one Line, and the Diameter of the Cylinder to be of nine Lines, then their Contents will be as 1 to 81. Then by this Analogy $1 : 81 :: 1\frac{1}{2} : 121\frac{1}{2}$, the Tube C D must have for its Length $121\frac{1}{2}$ Lines, (or 10 Inches $1\frac{1}{2}$ Line) so that the Liquor, which stood at G when the Mercury was near A in the Cylinder O X, will descend from G to C, when the Mercury shall

ſhall riſe from A to p P; and when it falls from A to L, the Liquor will riſe from G to D. In this manner may a Barometer be made, which ſhall be ſenſible, or moveable, to what degree you pleaſe. This Invention is very plain and ſimple, and much more eaſy to comprehend than Mr. *Huygens*'s former Barometer: But yet it has its Defects, which Experience has diſcover'd, and we ſhall ſhew here. Lect. X. Plate 21. Fig. 16.

The Oil of Turpentine ſticks to the Tube G D, ſo that when the Brandy riſes, it cannot wholly clear the Oil from the Tube, ſo that it is forc'd to go thro' the Oil, which makes it opake as well as the Tube. To prevent this Inconveniency, Philoſophers have endeavour'd to change the Liquors, taking a Solution of Pot-aſh and Oil of Petre; but this is no Cure for that Inconveniency, which ſtill remains the ſame, and they have never yet been able to correct this Fault by any kind of Fluid hitherto employ'd for this purpoſe. Perhaps hereafter Chemiſtry may ſupply us with ſome Fluids, leſs attracted by Glaſs, and conſequently leſs liable to adhere to it.

The lower Liquor of the Tube C D, and of the Cylinder C Z, is like that of a Thermometer, therefore one muſt always have a Thermometer at hand, whoſe Variations muſt alſo be large, in order to rectify the Height G in the Tube C D. It is therefore reaſonable to defer uſing this Barometer, till means have been found to remedy theſe two Inconveniencies.

22. The pendent Barometer, which uſed to be made and ſold by Mr. *Patrick*, (the late *Toricellian* Operator in the *Old Baily*) was really invented by Mr. *Amontons*, who publiſh'd a Deſcription of it in the Year 1695. He took a long Tube A B, whoſe Bore was conical, biggeſt at Bottom, and there only $\frac{1}{12}$ of an Inch wide. Let us ſuppoſe this Tube with the Hole downwards to hold 31 Inches of Mercury from A to C; as the whole Variation of the Height of the Mercury in the common Barometer is from 31 to 28 Inches, let us ſuppoſe the ſame Quantity of Mercury that was in A C to be but 28 Inches long, when it is in the lower Part of the Tube at D B; then it is certain, that when the Mercury ſtands at 31 Inches in the common Barometer, it muſt in this riſe up to A C, where the Column of Mercury will be 31 Inches long, on account of the Narrowneſs of the Tube: and when the Mercury is loweſt in the common Barometer, the Column in this muſt come down to D B, where, by the greater Width of the Tube, the Column will be ſhorten'd to 28 Inches; therefore the Courſe of the Mercury in this Barometer will be from A to D, whilſt it is but three Inches in the common Barometer. If then the Tube B A is of the Length of B D + D A = 28 + 31 = 58 Inches, the whole Motion of the Mercury in this Barometer will Plate 21. Fig. 17.

be

Lect. X. be of 31 Inches, which is above 10 times more than in the common Barometer. The Hole at Bottom B muſt be but $\frac{1}{12}$ of an Inch in Diameter, leſt the Mercury ſhould fall out of this open Tube; and then the Air preſſing upwards will ſuſtain it like a Bottom, or ſolid Piſton. Some Perſons uſed to call this a Sea-Barometer *, becauſe it may be carried conveniently to Sea inverted, and then held upright in the Hand in the Situation A B, when you want to uſe it. Therefore it has been much uſed within theſe 35 Years, and eſpecially at Sea; and to hinder the Mercury from coming out of it at Bottom, as it might happen at Sea by the Shake of the Ship, a little Cotton is thruſt up into the Tube near B, thro' which the Air preſſes freely: and if then by Accident ſome of the Mercury ſhould break off, and fall from the Column A D, you need only turn up the Tube, and what fell off will join again to the reſt. This Invention is very ſimple; but by many Years Obſervations the following Defects have been found in it. 1°. The Friction of the Column of Mercury againſt the inner Surface of the Tube is very great, becauſe that Column muſt riſe a great way in a little time. In the Caſe where there is 10 times as much Motion as in the common Barometer; when it is obſerv'd that the common Barometer is a little riſen, this has not mov'd at all: you muſt ſhake the Tube to make it riſe, and then it will riſe very much.

2°. Here is another Defect greater than the former. When you have ſhak'd the Tube, and obſerv'd where the Mercury ſtands, if you ſhake the Tube a ſecond time, the Mercury immediately riſes or falls, and does not come to the Place where it ſtood before. Yet it muſt be confeſs'd, that that Defect is the leſs, when you make uſe of a Tube where the Range of the Mercury is but twice or three times greater than in the common Barometer. It is very likely, that thoſe who praiſe this Barometer have not ſeen it, or at leaſt not compar'd it carefully with other Barometers. It may do for Seamen who are not very nice, but will not ſtand the Examination of a Philoſopher.

23. Here follows another ſort of Barometer, invented by Mr. *Dominick Caſſini*, and improv'd by that excellent Mathematician *John Bernouilli*. To a large Barometer Tube A B †, whoſe lower End B H is a little turn'd up, muſt be join'd at right Angles another Tube of a very ſmall Diameter (for Example, $\frac{1}{12}$ Inch) placed horizontally, and open at C, where it may be turn'd up about an Inch, tho' that is not neceſſary:

† Plate 21. Fig. 18.

* The marine Barometer is another kind of Inſtrument contriv'd ſince by Dr. *Hooke*, and ſhall be deſcrib'd in its Place; but this will hardly be of uſe, unleſs when the Motion of the Ship is extremely ſteady.

fary: I found it fufficient to have the Angle right at the Joint with B C. Lect. X.
Now let us fuppofe the Mercury to have a Motion of three Inches from D to L, as in the common Barometer, and that the Space D L contains as much as I C, the whole Cavity of the fmall Tube; then the Mercury of the Tube of the Barometer will ftand at D, when in the fmall Tube it will ftand at I. The Mercury defcending from D lower than $1\frac{1}{2}$ Inch, will fill the Space I E in the narrow Tube, and ftop at E; but if it continues to fall in the Tube A B from G to L, it will advance in the narrow Tube from E to C; and as the Diameter of the Tube A B may be taken in any Proportion to that of I C; for Example, of 100 to 1; this Barometer may be made as moveable as you pleafe, and even 100 times more fenfible than the common Barometer. The Conftruction of this Barometer is the eafieft of any I know, and deferves much to be valued, on account of its Inventors and great Range. Yet we may mention fuch Defects of it as Experience and Obfervation difcover. Air fometimes introduces itfelf between the Parts of the Mercury in the Tube I C, and feparates them from one another, when I C is too large. To remedy this Inconveniency, that Tube muft not be above $\frac{1}{12}$ of an Inch in Diameter, or even lefs, and the Mercury you ufe muft by Fire be purg'd of all its Air; the Tube I C muft alfo be very clean, and quite new. And yet, after all this, the Mercury grows foul in time by its Contact with the Air, which often caufes the Mercury to part as it moves from C towards I, at leaft fmall Globules break off, which ftop here and there in the fore part of the Tube that is empty. This Defect caus'd by a Separation in I C, is yet worfe, when you make ufe of Water, or other Liquors, as was done at firft. But there is another much more confiderable Fault; and that is, the great Friction of the Mercury againft the Glafs, which makes this Barometer even lefs fenfible than the common. I have indeed daily obferv'd, that when the Mercury moves in the common Barometer $\frac{1}{20}$, or $\frac{1}{10}$ of an Inch, it ftill remains in its Place in this Tube; but if the Variation increafes in the common Barometer, then the Mercury in I C moves very faft, and fometimes too far. If you ftrike the Place where the Inftrument hangs to make the Mercury vibrate, it will not return twice to the fame Degree: nay, it will differ an whole Inch, when I C is three Feet long. Notwithftanding all thefe Faults, this Barometer deferves to be improv'd, as we hear Mr. *Bulfinger* * is about it. Yet I don't know how the Friction in the Tube may be remedied, unlefs the Tube I C could be polifh'd in the Infide, and then I fear the Attraction of Cohefion would be ftill an Hindrance.

Plate 21. Fig. 18.

* See the *Petersbourgh* Tranfactions.

24. It wou'd be tedious to mention here any other Contrivances that have been invented to render Barometers more sensible than the common; but as they have all Defects, and the best of them are difficult to manage, I will only say here that the best Instrument of that Kind was invented by the Rev. Mr. *John Caswell*, Professor of Astronomy at *Oxford*. It is indeed only for present Use; but it is 1200 times more sensible than the common Barometer. Its Description with Calculations shewing its Sensibility, may be seen in the Notes *.

* Annot. 5.

25. But after all, the common Barometer is the best and the most lasting, and the most to be trusted to for good Observations, and by applying *Nonius*'s Divisions to the graduated Plate, one may know the Rise and Fall of the Mercury to the 100th or the 200th Part of an Inch: But unless it be well made and well fill'd (which is very difficult to do, and understood by few Workmen) there is no depending upon it: In order therefore to have the Barometer perfect, the following things are requir'd.

1st, The Tube must be new and very clean within, which you may be sure of if the Tube be hermetically seal'd at the Glass-House, to keep it free from any Dust till you use it, after having open'd one End of it with a File.

2dly, The Bore of the Tube must be large, to prevent the Effects of the Attraction of Cohesion, which hinders the free Rise and Fall of the Mercury. Not less than a quarter of an Inch; but I shou'd rather chuse $\frac{1}{3}$ of an Inch.

3dly, The Diameter of the Cistern that holds the stagnant Mercury must be very large in proportion to the Diameter of the Bore of the Tube, ten times greater at least; otherwise you will not have the right Measure of the Length of your Mercurial Column.

4thly, The Mercury must be very pure, and not falsified by the Mixture of any Metal.

5thly, The last thing to be consider'd is the preparing the Mercury and filling the Tube properly; which I learn'd from my learned and ingenious Friend Professor *P. V. Muschenbroek*, who is as accurate in making Experiments as he is faithful in relating them. According to him then we must proceed as follows:

Take the finest Mercury, no way falsified, and having strain'd it thro' a clean Leather, put it into a glaz'd Earthen Pipkin, which must be cover'd with a Cover that exactly fits it. This Pipkin must be set upon a clear Charcoal Fire, and there left till it boils: the Mercury then becomes volatile, but it is kept in by the Cover of the Pipkin. The Mercury thus

boiling

boiling is purg'd of the Air and Water that were mix'd with it. The Tube being just cut open at one end with a File, must be warm'd by a long Fire to make it equally hot all over, nay very hot, that all the Moisture and Air that sticks to it may go off from its Inside *. For want of this Caution, the Air will adhere so strongly to the Inside of the Tube, that it cannot be driven off by the Mercury that is pour'd into the Tube, but continues to stick in several Places. The better still to purge this Tube of Air, it would be well to fasten to a Wire a little Piece of shammy Leather, and make as it were a Pump-Piston of it, which must be work'd up and down in the Tube to rub off the Air that sticks to it within. By this means the Mercury which is now boiling may dissipate the whole Air, by making it go hot out of the Tube. Then with a Piece of a large Barometer Tube is made a long Glass Funnel by drawing one End of it into a long capillary Tube, which must be a little longer than the Tube to be fill'd. Take care to clean the upper Part of this Funnel, and to dry and warm it well at the Fire: then introduce it into the Barometer Tube so that it may reach to the Bottom, and pour in the boiling Mercury into this Funnel, which must be very hot, otherwise the Mercury will make it fly to pieces. The Mercury thus pour'd in, immediately goes to the Bottom, where it begins to fill the Tube, and rises up slowly. When once you begin to pour into the Funnel, you must go on without Intermission, that the Mercury may descend without the Air having any opportunity to get in between its Parts. When the Tube is full, draw out the little Funnel gently. This is the way of filling the Tube very exactly, which then will appear brown in all its Length without one Bubble of Air. If you have no Tubes seal'd at both Ends, you must, before you fill that which you use, clear it well within, washing it with Alcohol highly rectified, then rubbing it with a little Piston of shammy Leather fasten'd to a Wire, rub off the Air which otherwise wou'd stick to the Inside of the Tube.

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WHEN you wou'd know whether the Tube be well fill'd, you must shake it a little in the dark, so as to make the Mercury rise and fall: if then you see no light upon the Surface of the Mercury, it is a sign that the Barometer is perfect; but if it gives Light, it is not as it should be: for then you may be sure that there is a little Air above, to which the Light adheres. There are few Barometers but what give Light, when they are shak'd, which is a Proof of their Imperfection: If you let in a small

* If the Tube be moist within or without, it is then a non-electrick Body, and Air will stick to it strongly; therefore it will not be amiss to rub it with a dry Hand (or Paper) till you excite Electricity in it, which you will find by its attracting small Bodies; and then you may be sure that it will repel Air strongly, and then the Heat of the Fire will preserve it in that State. The Fire will indeed give this Electricity, but not so soon as rubbing.

Lect. X. ſmall Bubble of Air, ſo as to have it run up into the upper Part of a perfect Barometer which gives no Light, you will then perceive it to begin to ſhine. People uſed to imagine that the luminous Barometers were the beſt, but that is an error; for the contrary is obſerv'd. The Light which Barometers give is a Phænomenon, which has already given Philoſophers much trouble; and perhaps the Cauſe of their Opacity will give them as much. And indeed ſince Light eaſily paſſes thro' the Pores of the Glaſs, this Queſtion may be propos'd: Why does not Mercury ſhine without Air, and on the contrary why does it ſhine with Air? There is ſome probability that Light ſticks to the Air, and that coming along with it into the Tube thro' the Parts of the Mercury, it appears at the top of the Mercury, riſing and falling with its Surface, tho' it is ſometimes ſeen alone, when the Mercury falls in the Tube. The Light in the Tube of the Barometer has been obſerv'd in *France*, and a Deſcription of it given in the *Journal des Sçavans* for the Year 1676. The famous Mr. *John Bernouilli* has alſo treated of it at length in a Diſpute with Mr. *Nebel*.

When once you have a Barometer well made, you may obſerve that the Surface of the Mercury becomes convex in the Tube as ſoon as the Mercury begins to riſe, and that it becomes flat, when it is going to fall. This Convexity, which is form'd in the Middle, is caus'd by the Attraction of the Mercury to the Glaſs, as alſo by the rough Surface of the Glaſs, which hinders the whole Column of Mercury from riſing, as the Middle does, which is not expos'd to this Attraction and Friction. Conſequently if you conſider the Height of the Mercury in the Tube, as it touches the Sides of the Glaſs, you have not then the full Height of the Column of Mercury, which is *in æquilibrio* with the Height of the Atmoſphere, but you have a ſhorter Column: therefore you muſt ſhake the Tube lightly, or ſtrike it gently with your Finger, which will immediately ſet the Mercury in motion, and make it riſe in the Tube to its true Height. One may alſo conceive in the ſame manner, why the Surface of the Mercury becomes flat, when it is going to fall; the Middle of the Column of Mercury ſinks, whilſt the other Part of the Mercury ſtill ſticks to the Sides of the Tube; if then you ſtrike the Tube a little, or ſhake it, the Mercury quits the Glaſs and falls to its true Height. It is well to obſerve all theſe Circumſtances, when you wou'd make exact Obſervations with a Barometer.

26. There is a remarkable Experiment relating to the Barometer or *Toricellian* Experiment, which we muſt not paſs over without notice; and is this. If you have a Glaſs Tube of a ſmall Bore, and 70 or

or 80 Inches long, and you fill it with Mercury that has been thoroughly purged of Air in the manner above-mention'd, or any other way, provided it be pure and well cleans'd, when you invert it into a Veſſel of ſtagnant Mercury with care, and without ſhaking, the Mercury inſtead of coming down to 30 Inches, the Height at which the Preſſure of the Atmoſphere can ſuſtain it, will continue to fill the Tube, and not come down at all, and will (if nothing ſhakes the Place where this Tube is) continue in this Condition ſome Days; but by ſtriking the Tube with the Finger, or giving it a little ſhake, the Mercury comes down and ſtops at 30 Inches above the ſtagnant Mercury, or at any other Height between 31 and 28 Inches, according as the Mercury ſtands in the common Barometer. Mr. *Boyle* alſo obſerved the Mercury to riſe up to 60 Inches in the Gage-Tube of his Air-Pump. Mr. *Huygens* likewiſe tried the Experiment; and Profeſſor *Muſchenbroek*, and many others, as well as myſelf, have made the Experiment. This Phænomenon would ſeem difficult to ſolve, if we were not acquainted with the Power of the Attraction of Coheſion, that acts ſtrongeſt in Contact; for when the Mercury is well purg'd of Air, many Parts of the Mercury, which wou'd by the Interpoſition of little Bubbles of Air be kept from touching the Tube, are brought into Contact with it, and thoſe Particles that are in the Middle of the Column touch and ſtick to thoſe that are next to the Sides of the Tube, making, as it were, a ſolid Column for that time. That all this is owing to the Attraction of Coheſion is plain; becauſe the Experiment will not ſucceed when the Mercury is not well purg'd of Air; or even then if the Bore of the Tube is large. This is the reaſon why the Barometers carried about the Streets to be ſold, or ſold cheaper than ordinary in Shops, becauſe of the ſmall Quantity of Mercury in them, are all good for nothing, as their Tubes are ſmall and the Attraction of Coheſion makes the Mercury ſtick to the Sides of the Tube ſo as not to riſe and fall according to the Preſſure of the Atmoſphere exactly, as may be ſeen by comparing them with other Barometers.

Now we come to ſhew the Cauſes of the riſing and falling of the Mercury in the Barometer, or of the Cauſes of the Air's greater and leſs Preſſure upon the ſtagnant Mercury; which I cannot do better than by giving the Subſtance of our late Geometry Profeſſor Dr. *Halley*'s excellent Diſcourſe upon this Subject, as he has publiſh'd it in the *Philoſophical Tranſactions* N° 187. ſince I wholly acquieſce in his Opinion of the Cauſes of the various Preſſure of the Air, and the Cauſe of Rain; tho' I intirely differ from him, as to the Cauſe of the Riſe of Vapours and Formation of Clouds; of which my two Diſſertations annex'd to this Lecture will ſhew my Opinion.

27. *Dr.* E. HALLEY'*s Discourse upon the Reasons of the Rise and Fall of the Mercury in fair and foul Weather.* The Substance of which is as follows:

I. HE premises the commonly observ'd Phænomena of the Mercurial Baroscope; which are,

1. THAT in calm Weather when the Air is inclined to Rain, the Mercury is commonly low.

2. THAT 'tis generally high in good, serene, settled, fair Weather.

3. THAT it sinks lowest of all on very great Winds, though they are not accompanied with Rain; with relation to the Point of the Compass the Wind blows upon.

4. THAT, *cæteris paribus*, the greatest Height of the Mercury is found, when an Easterly or North-Easterly Wind blows.

5. THAT in calm frosty Weather the Mercury generally is high.

6. THAT after very great Storms of Wind, when the Mercury hath been low, it usually rises again very fast.

7. THAT the more Northerly Places have a greater Alteration of the Rise and Fall of the Mercury, than the more Southerly.

8. THAT within the Tropicks, and near them, there is little or no Variation of the Mercury's Height in all Weathers.

28. *The Theory that Dr.* HALLEY *advances to solve all which Phænomena, is this:*

1. HE supposes the principal Cause of the Rise and Fall of the Mercury, is from the variable Winds, which are found in the temperate Zones, and whose great Inconstancy here in *England* is most notorious.

2. A SECOND Cause is the uncertain Exhalation and Precipitation of Vapours lodging in the Air, whereby it comes to be at one time, much more crouded than at another, and consequently heavier; but those latter, in a great measure, depend upon the former. Now from these Principles, he explicates the several Phænomena of the Barometer.

1. WHY in calm Weather, the Air being inclined to Rain, the Mercury is commonly low?

THAT the Mercury's being low is an Indication of Rain, because the Air being light, the Vapours are no longer supported thereby, as being become specifically heavier than the Medium wherein they floated; so that they descend towards the Earth, and in their Fall meeting with other aqueous Particles, they incorporate together, and form little Drops of Rain; but the Mercury's being at one time lower than at another, is the

the Effect of two contrary Winds blowing from the Place where the Barometer stands; whereby the Air of that Place is carried both ways from it, and consequently, the incumbent Cylinder of Air is diminished, and accordingly the Mercury sinks: as, for instance, if in the *German* Ocean it should blow a Gale of Westerly Wind, and at the same time an Easterly Wind in the *Irish* Sea; or if in *France*, it should blow a Southerly Wind, and in *Scotland* a Northern, it must be granted me, that that Part of the Atmosphere, impendent over *England*, would thereby be exhausted, and attenuated, and the Mercury would subside, and the Vapours which before floated in those Parts of the Air of equal Gravity with themselves, would sink to the Earth.

2. Why, in serene, good settled Weather, the Mercury is generally high?

That the greater Height of the Barometer, is occasioned by two contrary Winds blowing towards the Place of Observation, whereby the Air of other Places is brought thither, and accumulated; so that the incumbent Cylinder of Air being increased both in Height and Weight, the Mercury press'd thereby, must needs rise and stand high, as long as the Winds continue so to blow; and then the Air being specifically heavier, the Vapours are better kept suspended, so that they have no Inclination, to precipitate and fall down in Drops, which is the reason of the serene good Weather which attends the greater Heights of the Mercury.

3. Why, upon very great Winds or Storms, though accompanied with no Rain, the Mercury sinks lowest of all, with relation to the Point of the Compass upon which the Wind blows?

This is caused by the very rapid Motion of the Air in these Storms; for the Tract or Region of the Earth's Surface wherein these Winds range, not extending all round the Globe; that stagnant Air, which is left behind, as likewise on the Sides, cannot come in so fast as to supply the Evacuation made by so swift a Current; so that the Air must necessarily be attenuated when and where the said Winds continue to blow, and that more or less according to their Violence. Add to which, that the horizontal Motion of the Air, being so quick as it is, may in all probability take off some Part of the perpendicular Pressure thereof*; and the great Agitation of its Particles is the reason why the Vapours are dissipated, and do not condense into Drops, so as to form Rain; otherwise the natural Consequence of the Air's Rarefaction.

* Ann. 6.

4. Why, *cæteris paribus*, the Mercury stands highest upon an Easterly or North-Easterly Wind?

This happens, because that in the *Atlantick* Ocean, on this side the 35th Degree of North Latitude, the Westerly and South-Westerly Winds blow

Lect. X. blow almost always Trade; so that whenever here the Wind comes up at East and North-East, 'tis sure to be check'd by a contrary Gale, as soon as it reaches the Ocean; wherefore, according to what is made out in the second Remark, the Air must needs be heaped over this Island; and consequently the Mercury must stand high, as often as these Winds blow. This holds true in this Country, but is not a general Rule for others, where the Winds are under different Circumstances; and he himself hath sometimes seen the Mercury here as low as 29 Inches upon an Easterly Wind, but then it blew exceeding hard, and so comes to be accounted for by what was observed upon the third Remark.

5. WHY in calm frosty Weather the Mercury generally stands high?

THE Cause thereof is, that it seldom freezes but when the Winds come out of the Northern and North-Eastern Quarters; or at least, unless those Winds blow at no great distance off: for the Northern Parts of *Germany*, *Denmark*, *Norway*, *Sweden*, and all that Tract from whence North-Eastern Winds come, are subject to almost continual Frost all the Winter; and thereby the lower Air is very much condensed, and in that state is brought hitherwards by those Winds, and being accumulated by the Opposition of the Westerly Wind blowing in the Ocean, the Mercury must needs be pressed to a more than ordinary Height; and as a concurring Cause, the shrinking of the lower Parts of the Air into lesser room by Cold, must needs cause a Descent of the upper Parts of the Atmosphere to reduce the Cavity made by this Contraction to an Æquilibrium.

6. WHY, after very great Storms of Wind, when the Mercury has been very low, it generally rises again very fast?

THIS, he tells you, he has frequently observed, and once found it risen an Inch and a half in less than six Hours, after a long continued Storm of South-West Wind. This seems to be occasioned by the sudden Accession of new Air to supply the great Evacuation which such continued Storms make thereof in those Places where they happen, and by the Recoil of the Air, after the Force ceases that impelled it; and the Reason why the Mercury rises so fast, is, because the Air being so much rarefied beyond its mean Density, the neighbouring Air runs in the more swiftly to bring it to an Æquilibrium; as we see Water runs the faster for having great Declivity *.

* Ann. 7.

7. WHY, in more Northerly Places, the Variations of the Barometer are greater than in more Southerly?

THE Truth of the Matter of Fact is proved from Observation made at *Clermont* and *Paris*, compared with others made at *Stockholm*; as may be seen in the Appendix to Mr. *Pascal*'s Book *de l'Equilibre des Liqueurs*. The Reason seems to be, that the more Northerly Parts have usually

greater Storms of Wind than the more Southerly, whereby the Mercury should sink lower in that Extreme; and then the Northerly Winds bring the condensed and ponderous Air from the Neighbourhood of the Pole; and that again being check'd by a Southerly Wind, at no great Distance, and so heaped, must of necessity make the Mercury in such case stand higher on the other Extreme. Lect. X.

8. Why near the Equinoctial, as at *Barbadoes* and *St. Helena*, there is very little or no variation of the Height of the Barometer?

This Remark, above all others, confirms the Hypothesis of the variable Winds, being the Cause of these Variations of the Height of the Mercury; for in the Places above-named, there is always an easy Gale of Wind blowing nearly upon the same Point, *viz.* E. N. E. at *Barbadoes*, and E. S. E. at *St. Helena*; so that there being no contrary Current of the Air, to exhaust or accumulate it, the Atmosphere continues much in the same state: However, upon Hurricanes, the most violent of Storms, the Mercury has been observed very low; but this is but for once in two or three Years, and it soon recovers its settled State of about $29\frac{1}{2}$ Inches; and there is no doubt but the same thing is in the East Coast of *Africa*, and in *India*, where the Monsoons or Winds are Trade for half the Year one way, and half the Year another: only it is probable, that there may something worth noting happen, about the time of the Change or Shifting of the Winds; which might be obtain'd, if any body had the Curiosity to keep the Barometer at our Factories in *India*.

Snowdon Hill in *North Wales* was measured by Mr. *Caswell* with Mr. *Adams*'s Instruments, and found to be 1240 Yards high.

Dr. *Halley* found by three exact Trials, the Mercury in the Baroscope descended at its Top three Inches eight Tenths, and something more, and perhaps four Inches may be near enough Truth; if so, then divide 1240 by 4, the Quotient is 310 Yards: so that any Fall of the Mercury one Inch argues an Ascent of just 310 Yards in height; but according to Dr. *Halley*'s Account of three and eight Tenths of Inches, he makes 30 Yards height to answer to one Tenth of an Inch Fall: we therefore allow just 30 Yards, for Dr. *Halley* thought the Fall of the Mercury more than $3\frac{8}{10}$ Inches.

The following Rules, to judge of the Weather by the Barometer, used to be given by Mr. John Patrick, *in* Ship-Court *in the* Old-Bailey, *the Toricellian Operator; and they were the Result of his own long Experience and Observation.*

29. Rules and Observations on the various rising and falling of the Mercury, to foreknow the Weather by the Barometer.

I.

Lect. X. 1. It hath been obſerved, that the Motion of the Mercury doth not exceed 3 Inches in its riſing or falling, in the Barometer of the common Form.

2. That its leaſt Alterations are to be minded, in order to the right finding the Weather by it.

3. The riſing of the Mercury preſages, in general, fair Weather; and its falling, foul; as Rain, Snow, high Winds, and Storms.

4. In very hot Weather, the falling of the Mercury foreſhews Thunder.

5. In Winter, the riſing preſages Froſt; and in froſty Weather, if the Mercury falls three or four Diviſions, there will certainly follow a Thaw; but in a continued Froſt, if the Mercury riſes, it will certainly ſnow.

6. When foul Weather happens ſoon after the falling of the Mercury, expect but little of it; and judge the ſame when the Weather proves fair ſhortly after the Mercury is riſen.

7. In foul Weather, when the Mercury riſes much and high, and ſo continues for two or three Days before the foul Weather is over, then expect a Continuance of fair Weather to follow.

8. In fair Weather, when the Mercury falls much and low, and thus continues for two or three Days before the Rain comes, then expect a great deal of Wet, and probably high Winds.

9. The unſettled Motion of the Mercury denotes uncertain and changeable Weather.

10. You are not ſo ſtrictly to mind the Words engraved on the Plates, tho' for the moſt part it will agree with them, as the Mercury's riſing and falling; for if it ſtands at much Rain, and then riſes up to changeable, it preſages fair Weather; altho' not to continue ſo long as it would have done, if the Mercury were higher; and ſo on the contrary.

N. B. The Cauſe of the 6th, 7th, and 8th of Mr. *Patrick*'s Articles are explain'd in the Notes *.

* Ann. 8.

About the Year 1710, Monſ. *Leibnitz* advanced a new Principle to explain the Cauſe of the Variation of the Barometer, in a Letter which he wrote to the Abbé *Bignon*; which Monſ. *Fontenelle*, Secretary of the *Royal Academy of Sciences* at *Paris*, illuſtrates in the Hiſtory of the ſaid Academy for the Year 1711. As that Principle is falſe, I made Remarks upon it in the Year 1719, and as they are ſuitable for this Subject, I ſhall inſert them here, having firſt quoted Monſ. *Fontenelle*'s Account and Illuſtration of Monſ. *Leibnitz*'s Principles.

Monſ.

Monſ. *Fontenelle's* Paper is as follows:

30. It appears by the Barometer, that when it rains, or a little before Rain, the Air commonly becomes lighter. That it muſt rain when the Air becomes lighter, it is eaſy to imagine: for the imperceivable Particles of Water, that ſwim about in the Air in prodigious quantity, not being ſufficiently ſuſtained when the Air has loſt a certain Degree of its Weight, begin to fall, and ſeveral of them joining together in the Fall, make Drops of Rain. So when about half the Air is drawn out of the Recipient of the Air-Pump, (and conſequently the remaining Air is as weak again as at firſt) ſomething like a ſmall Rain falls. But why ſhould the Air become lighter? One might imagine that in the Place where it rains, it may have loſt ſome of its Weight and Bulk, by means of the Wind's carrying away ſome part of it: but Monſ. *Leibnitz*, in a Letter to the Abbot *Bignon*, gives a more ingenious and more new Reaſon for it. He pretends that *a Body, which is in a Liquid, weighs with that Liquid; and makes up part of its whole Weight, ſo long as it is ſuſtained in it; but if it ceaſes to be ſuſtained, and conſequently falls, its Weight makes no longer a part of the Weight of the Liquid, which thereby comes to weigh leſs.* This may naturally be applied to the abovementioned Particles of Water; they increaſe the Weight of the Air, when it ſuſtains them, which is diminiſhed when it lets them fall: and as it may often happen, that the Particles of Water that are higheſt, fall a conſiderable time before they join with thoſe that are low, the Gravity of the Air diminiſhes before it rains, and the Barometer ſhews it. This new Principle of Monſ. *Leibnitz's* is ſurpriſing: For muſt not a ſtrange Body, whether ſuſtain'd in a Liquid or not, always weigh? Can it gravitate upon any other Bottom than that which ſuſtains the whole Liquor? Does that Bottom ceaſe to carry a ſtrange Body, becauſe it falls? And is not that Body all the while it is falling, part of the ſaid Liquid, as to the Weight? At that rate, whilſt a chymical Precipitation is made, the whole Matter ought to weigh leſs, which has never been obſerved, and ſcarce appears credible. Notwithſtanding theſe Objections the Principle holds good, when more cloſely examined. What ſuſtains a heavy Body is preſs'd by it. A Table, for example, which ſuſtains a Pound Weight of Iron, is preſs'd by it, and is ſo only becauſe it ſuſtains the whole Action and Effect of the Cauſe of Gravity (whatever it be) to puſh that Lump of Iron lower. If the Table ſhould yield to the Action of that Cauſe of the Weight (or Gravity,) it would not be preſs'd, and therefore would carry nothing. After the ſame manner the Bottom of a Veſſel, which contains a Liquid, oppoſes itſelf to all the Action of the Cauſe of Gravity

Lect. X. against the said Liquid: If a strange Body swims in it, the Bottom opposes itself also to the said Action against that Body, which, being *in æquilibrio* with the Liquid, is in that respect really a Part of it. Thus the Bottom is press'd both by the Liquid and the strange Body, and sustains them both. But if the Body falls, it yields to the Action of Gravity, and consequently the Bottom does no longer sustain it, till the same Body is come down to the Bottom. Therefore, during the whole time of the Fall, the Bottom is eased of the Weight of that Body, which is no longer sustained by any thing, but push'd down by the Cause of Gravity, to which nothing hinders it from yielding. Monsieur *Leibnitz*, to confirm this Notion, proposed an Experiment. He says, that two Bodies must be tied to the two Ends of a Thread, the one heavier, and the other lighter than Water, yet such as both together may swim in Water: Put them into a Tube full of Water, the Tube being tied to one End of the Beam of a Balance, whose other End has a counterpoising Weight. Then if we cut the Thread which ties the Bodies together, (that are of unequal Weight) so that the heaviest may presently descend, he says, that in such a case the Tube would be no longer *in æquilibrio*, but its counterpoising Weight would preponderate, because the Bottom of the Tube would be less press'd. It is plain, that the Tube must be sufficiently long, that the falling Body may not reach the Bottom before the Tube has Time to rise. In chymical Precipitations, the Vessels are either too short, or what is precipitated falls sometimes too fast, and sometimes too slow; for then the little Bodies are always (as to Sense) *in æquilibrio* with the Liquor that contains them.

Monsieur *Ramazzini*, the famous Professor at *Padua*, to whom Monf. *Leibnitz* had proposed his Experiment, has made it with success, after some fruitless Trials. Monsieur *Reaumur* (to whom the Academy had recommended it) has also made it with success. This is a new View in natural Philosophy, which, tho' it depends upon a well-known Principle, is very subtle and far-fetch'd; and gives us just reason to fear, that in Subjects that seem to be exhausted, several Things may yet escape us.

Remarks upon Monsieur Leibnitz's *new Principle.*

Plate 21. *Fig.* 21.

Plate 21. Fig. 21. 31. Let A B be the Bottom of a Vessel full of any Fluid, whose Top is either wider than the Bottom, as G H; narrower, as E F, or equal to it, as C D. The Pressure of the Fluid upon the Base A B will be equal to the Weight of C B, or of a Cylinder or Prism of the same Fluid,

Fluid, made up of the Area of the Base multiplied into the particular Height above it. If the Fluid be equally denſe every way as Water, or of a Denſity uniformly diminiſhed as you go upwards, this Propoſition, call'd by Mr. *Boyle* the Hydroſtatical Paradox, will hold good. This is demonſtrated by all Hydroſtatical Writers. Lect. X. L. 7. N° 16.

Plate 21. *Fig.* 22.

Let E F repreſent part of the Surface of the Earth, and G E F H a Pillar of the Atmoſphere, whoſe Height is G E, the whole Height of the Air. Let us imagine the Vapours riſing out of the Earth to form themſelves into two Clouds A and B, and to ſettle in that Place where the Air is of the ſame ſpecifick Gravity with themſelves. It is evident that they will cauſe the Air to riſe ſo much higher as their Bulk amounts to, and will therefore make the Surface, which was at G H, to riſe up to I K, ſo that the Bottom E F, which was preſs'd by a Pillar of Air, as G E F H, is now preſs'd by an higher Pillar I E F K. Now if the Clouds A, B, by any Cauſe ſoever, change their place, ſo as to come downwards, (for Example, to C, D) the Height of the Pillar I E F K will remain the ſame as it was, and therefore the Bottom E F will be preſs'd as before, by the foregoing Propoſition. Plate 19. Fig. 22.

Corollary 1.

If the Clouds A, B deſcend, and in their Deſcent keep the ſame Bulk as they had before, the Surface I K will remain the ſame, and therefore E F will be preſs'd as before.

Corollary 2.

Whether a Body be ſpecifically lighter, or ſpecifically heavier than a Fluid; ſo long as it is detained in it, it will add to the Fluid as much Weight as the Weight of an equal Bulk of that Fluid *: Wherefore a Body does not loſe all that Weight which it added to the whole Weight of the Fluid, when it ceaſes to be ſuſtained in the ſaid Fluid: contrary to Monſ. *Leibnitz*'s Principle.

* L. 8.

Scholium.

If a Cloud, by any Cauſe whatſoever, becomes ſpecifically heavier than that Part of the Air in which it ſwims, the Exceſs of its Gravity above an equal Bulk of Air will make it deſcend, and accelerate its Motion downward; and then indeed it will loſe of its Weight by the Reſiſtance of the Medium, till it comes to an uniform (or ſenſibly uniform) Motion; but all the Weight that it will loſe will only be the Exceſs of its

Lect. X. its Gravity above that of the Air: for with the reſt of its Weight it will ſtill make up Part of the Weight of the Air *.

* L. 9. N° 1. Page 185, & ſeq.

EXPERIMENT 8. *Plate* 21. *Fig.* 23.

Plate 19. Fig. 23. HAVING with a Weight in the Scale C of the Balance A B counterpoiſed the long Glaſs of Water E I, with a Horſe-hair, I let down the leaden Weight W into the Water, which from E G aroſe up to E H; and therefore the Water became heavier by the Weight of the Bulk of Water equal to the Lead *. Having with another Weight in C made up the Counterpoiſe to the whole, with fine Sciſſars I cut the Thread of the Plummet; and all the while the Plummet was falling, the Water deſcended rather than roſe; and when the Lead was at the Bottom, the Water overpoiſed, becauſe it had then added to it all the Exceſs of Weight of the Lead above an equal Bulk of Water, which by Experiment is about $\frac{10}{11}$ of its Weight *. Had Meſſieurs *Reaumur* and *Ramazzini* try'd the Experiment thus, the Succeſs had been the ſame; but Monſ. *Ramazzini* (as I underſtood from a Gentleman who was preſent) tried it in the following manner, as I have ſince done.

* L. 9. N° 1. Page 185, & ſeq.

* L. 9. N° 1.

EXPERIMENT 9. *Fig.* 24.

Plate 19. Fig. 24. MAKING uſe of the above-mentioned Machine, after I had balanced the Water and Lead in it, I fixed to the End of the Beam B the Thread of the Plummet, which in the former Experiment I held in my Hand. This added to the Weight hanging at B, and oblig'd me to put into the other Scale a Weight equal to $\frac{10}{11}$ of the Lead, to recover the *Æquilibrium*. Then cutting the Thread or Hair, the Scale with the Weights overpois'd whilſt the Lead was falling; but the *Æquilibrium* was reſtored when it came to the Bottom. So that the Lead even then muſt have loſt only its Exceſs of Weight above Water.

EXPERIMENT 10. *Fig.* 25.

Plate 19. Fig. 25. I TRIED the way propoſed by Monſ. *Leibnitz* in the following manner. I took a Cork C weighing an Ounce, and ſomething more than four times lighter than an equal Bulk of Water, and a Ball of Antimony W about four times ſpecifically heavier than Water, and of four Ounces Weight. The Cork laid upon the Water in the Veſſel E A B D raiſed the Water from S S to G G, and added an Ounce to the Weight of the whole Water *. Then ſuſpending the Ball of Antimony by a String, and letting it hang in the Water at N, it raiſed the Water from G G to H H, and ſo added another Ounce to the Weight of the Water *. Then tying the Antimony to the Cork, (ſee the Figure of the Veſſel mark'd with

* L. 9. N° 1.

* L. 9. N° 1.

with little Letters) the Cork had added to it three Quarters of the Weight of the Antimony, which the Hand before had ſuſtained, and made it ſink ſo as to be almoſt covered, and raiſed the Water to *i k*, adding three Ounces to its Weight *. Hanging this Veſſel of Water upon the Balance, and a Counterpoiſe at the other End, upon cutting the String the Veſſel of Water was rais'd up, and the *Æquilibrium* was not reſtored till the Antimony came to the Bottom. Lect. X. Plate 19. Fig. 25. * L. 9 N° 1.

By obſerving that as the Cork, being freed from the Weight of the Antimony, aroſe, and that during the Fall of the Body, the Water ſunk to *h h*, it appears that this is, in effect, the ſame Experiment as the former, and concludes no more. As to the real Cauſe of the Variation of the Barometer; namely, the Accumulation of Air by Winds over the Place where the Barometer riſes; and Part of the Air being blown away where the Mercury in the Barometer ſinks, ſee Dr. *Halley*'s Account of it in the *Phil. Tranſactions*, Numb. 181. and the Account of it here, Page 278, & *ſeq.*

Postscript.

In making the firſt Experiment before the Royal Society, of a Piece of Lead ſuſpended by a Thread, whilſt it was wholly covered with Water in the large Tube in which it hung, (whoſe Length was four Feet) it was obſervable, not only that the End of the Balance (to which the Tube of Water with the Lead in it was fixed) did not riſe when the Thread was cut, (to let the Lead fall from the Top to the Bottom of the Tube) as it muſt have done according to Mr. *Leibnitz*'s Principle; but that the ſame End of the Balance began to deſcend from the Time that the Lead began to fall. Therefore, to be ſure that it was not the Plummet's rubbing againſt the Sides of the Tube in its Fall, which cauſed that Phænomenon, I hung to the Balance a long Glaſs of three Inches Diameter inſtead of the Tube, and making the Experiment as before, it ſucceeded in the ſame manner; the End of the Balance which carried the Veſſel of Water, ſunk as ſoon as the Thread of the Plummet was cut; tho' this Glaſs was not above half ſo long as the Tube.

When by holding the String I drew the Lead upwards and downwards in the Water, there was no ſenſible Alteration of the *Æquilibrium*. Neither was it altered by cutting the String of a Stone Plummet, becauſe of the Shortneſs of the Glaſs, and the little Exceſs of ſpecifick Gravity in the Stone: for the greater the Difference is betwixt the Body made uſe of in this Experiment and Water, as well as the bigger the Body itſelf is, the better the Experiment will ſucceed.

Hence it appears, that when a Body ſpecifically heavier than a Fluid, is, by what Cauſe ſoever, detained in any Place of the ſaid Fluid, it adds

as

Lect. X. as much to the Weight of the whole Fluid as an equal Bulk of the same Fluid amounts to *: And when the said Body, by the Action of its Excess of specifick Gravity above the Fluid, descends with an accelerated Motion; so long as that Motion is accelerated, the Resistance of the Fluid (which is as the Square of the Velocity) takes off something of the Weight of the Body; but as much as the Body loses, so much the Water gains *, over and above what was given it by its rising on account of the immersed Body.

* L. 9. N° 1. Page 185. & seq.

* L. 9. N° 1.

A Body therefore *that falls in a Fluid, is so far from making the Fluid lighter as it falls, that it makes it press more upon the Bottom that sustains it, when it is falling, than when it was at rest in the Fluid.* If the Vessel of Water be long enough for the falling Body to come to an uniform Motion before it reaches the Bottom, the Force impress'd on the Water under the Body will make it press the Bottom as much as if the Body were actually at Bottom; the Body in that case losing all its Excess of Gravity above that of the Water, and the Water gaining it *.— Hence it follows, that a falling Cloud, when it comes to an uniform Motion, will not only add to the Weight of the Air as much as the Weight of an equal Bulk of Air; but even as much as its whole Weight amounts to, tho' it be specifically heavier than the Air about it.

* L. 9. N° 1.

All the Diminution of Weight that can be allow'd in this case is this. If we imagine the Air to have a smooth, regular Surface, as we have at first supposed, (or if that be not allow'd, we may take any imaginary Surface of it, above the Clouds) when a falling Cloud is diminished in Bulk, (as when it is changed into Rain) the Surface of the Air will subside in proportion to that Diminution, and therefore will weigh less, by so much as is the Weight of a Quantity of Air equal to the Bulk that Cloud has lost: But when the Drops of Rain after their Acceleration (occasion'd by their Excess of Gravity above that of the Air) are come to an uniform Motion of the Resistance of the Air, they restore to the Air the Weight that it had lost. Now this uniform Motion being acquir'd in about two Seconds of Time, and the Diminution of Gravity in the Air being insensible, when compar'd to near three Inches of Mercury, (for such is the Variation of the Barometer with us) can no way be the Occasion of those so sensible Alterations in it, which happen some time before Rain or fair Weather.

Add to this, that the whole Quantity of Rain that falls in *England* and *France*, in the space of one Year, scarce ever equals two Inches of Mercury; and in most Places between the Tropicks, the Rain falls at certain Seasons in very great Quantities, and yet the Barometer shews there very little or no Alteration *.

* Ann. 9.

32. The Experiments that have been made to measure the Height of Hills with the Barometer, are much less to be depended upon than one would imagine; for some Philosophers used to fill the Tube, and invert it into its Bason at the Bottom of the Hill, to see how high the Mercury stood there: then they emptied the Tube, to carry the Instrument to the Height where they made the next Experiment, where they fill'd the Tube a-new, and observ'd the Height of the Mercury in the Tube. But, let them take what Care they could, they could not purge the Tube and Mercury of Air, as it ought to be, which would make the Mercury stand lower than it ought to do: and therefore the Consequences drawn from such Experiments must be wrong, especially when we consider how difficult it is to fill a Barometer well, as we have shewn. It is only since the portable Barometer has been invented that Experiments to measure Heights may be relied on; and since they must be made with such a Barometer, it was not improper to give its Description here, and to shew how it ought to be made, in order to be perfect in its kind.

A Description of the portable Barometer. *Plate* 21. *Fig.* 19.

o L K *p* is a wooden Box open at Bottom at *o p*, that when it is inverted it may slide on, and be fix'd to the lower Part of the Frame of the whole Machine, whose Bottom *o p* H is only represented in this Figure, where we have put the Letters out of the Scheme to avoid Confusion, with Lines conducted to them from the Parts they refer to. A and B point to the Cavity of the Box, which is conick at top, but cylindrick in the middle Part. Below that cylindrick Cavity there is another cylindrick Cavity so much wider than the first, that the Ring N (whose inner Cavity is just equal to the Cylinder B) may just fit into it so as to press against its Sides a Piece of soft Sheep's Leather, which makes a Diaphragm at C, where it can rise and fall convex, or concave, whilst its outward Part is glew'd to the End of the Ring above-mentioned, and fasten'd to the Box by that means. Now before this Diaphragm be glued in, the Box must be turn'd up, and the Tube K I hermetically seal'd at I must be put thro' the Hole K, till its open End is about the middle of the Box, and then it must be cemented very tight from the conick Part to K. When the Cement is dry, and the Peg of Wood L going from the external to the internal Part of the Box, is twisted in fast; the Tube must be well clean'd, and the Mercury pour'd into it after Professor *Muschenbroek*'s manner, till it is quite full. Then the whole Box and Cylinder is to be fill'd with Mercury up to the Place where the cylindrick Cavity is wider, but no higher. Next is to be put on the Leathern Diaphragm,

Plate 21. Fig. 19.

Lect. X. Plate 21. Fig. 19.

phragm, which is to be pasted, glued, or gumm'd for about half an Inch round its Edge, so as to stick to the Box as well as to the Ring N abovementioned, thrust on after it at E. This being done, join the Bottom of the Frame of the Machine to the Box, by turning it upside down, and sliding it into the Mouth of the Box, having first prepar'd it in the following manner: To a Brass Button H is fasten'd a thick Brass Wire, having a triple Male Screw towards its Top, with a Plate of about an Inch in Diameter and $\frac{1}{10}$ of an Inch in Thickness, riveted to its Top in order to press occasionally against the Leathern Diaphragm, and, from its being concave, or convex downwards, to lift it with all the Mercury upon it, and make it convex upwards. A Brass Plate G fasten'd to the Wood has a female Screw in it to guide the Wire in its rising to push up its Plate. The whole Machine then is to be made fast together, and to the rest of the Frame, and set upright. Then the Mercury will fall to M the true Height of the Mercury in the Barometer (supposing the Plate M so fix'd, that from the Bottom of it to the Surface of the Mercury in the Box the Distance be 28 Inches, and the Diameter of the Box be so much larger than that of the Tube, that a Fall of 3 Inches in the Tube will not sensibly raise the Mercury in the Box, and the Bore of the Tube it self must be so large, that the Attraction of Cohesion does not hinder the free Motion of the Mercury). In this case the external Air pressing upwards pushes against the Leather and Quicksilver in the Box, whilst the short Columns of Air pressing by their Spring on the Surface of the stagnant Mercury, and the Column of Mercury in the Tube, make a Counterbalance to this Pressure, and vary with it. When you wou'd carry this Barometer from Place to Place, to make Experiments at different Heights and Distances, you must turn the Button H, by it to screw up the Plate F, which will drive up the Mercury so as to fill up not only the Tube quite to the Top, but also the Cavity A and the whole Box, which was empty before. Then the Mercury being as one solid Cone, having no Jerks against the Top of the Glass, the Barometer is very safely carried. Then turning back the Screw, the leathern Diaphragm is let down and the Mercury with it, so that it falls to its true Height in the Tube; because the Air will pass freely thro' the Wood of the Box, most Wood being pervious to Air; but sometimes when Wood is varnish'd, it checks the Air a little in its Passage, and I have seen a Deficiency of a 10th or $\frac{2}{10}$ of an Inch in the Height of the Mercury: therefore to prevent any such Accident, it is expedient to have a Peg of Wood to go thro' the Box at L, whereby you open a way into the Box when you set up the Barometer by way of Experiment, where it is easy to set it per-

pendicular;

pendicular; becauſe then the Mercury will be loweſt. The 20th Figure repreſents the portable Barometer, with a Thermometer join'd to it. Lect. X.

THE THERMOMETER is an Inſtrument contriv'd for meaſuring the Degrees of Heat in Bodies, eſpecially the Heat or Cold of the Weather; for which Reaſon it was call'd the Weather-Glaſs, before the Barometer was invented, and the Weight of the Air was known. Its Invention is attributed to ſeveral Perſons by different Authors, *viz. Sanctorio, Galileo,* Father *Paul*, and *Drebbel*; but at firſt it was very imperfect, being made of Air, whoſe Property of expanding by Heat and condenſing by Cold was known, tho' its Weight and Preſſure (which cauſed their Obſervations to be falſe) they were ignorant of.

EXPERIMENT 11. *Plate* 22. *Fig.* 1.

TAKE a Glaſs Tube about two Foot long open at one End *d*, having at its other End a Ball as B; then having warm'd the Ball B, ſomething more than the Heat of a warm Summer Sun, plunge the open End *d* of the Tube into ſome colour'd Liquor (Spirit of Wine ting'd with Cochineal is good, becauſe it won't eaſily freeze) in a Veſſel C*c*, and the Liquor will riſe up into the Tube to a certain Height; for Example, to SS. This is the old Weather-Glaſs or Air-Thermometer. As the Air in the Ball will condenſe it ſelf, and take up leſs room, when the Weather grows colder, the Liquor in the Tube will riſe up towards W W, in proportion to the diminiſh'd Space of the Air. If the Weather grows hotter, the Air will expand it ſelf and puſh down the Liquor towards *d*. This riſing and falling of the Liquor was the means whereby People judged of the Alterations of the Weather, ſuppoſing it to be colder in proportion to the riſing of the Liquor in the Tube, and hotter in proportion to its Fall. Sometimes the Tube was recurv'd and without a Ciſtern of Liquor, which was contain'd in the Bottom of the Ball and Part of the Tube; and in this caſe the Riſe of the Liquor would ſhew hot Weather, and its Fall, cold. But when the Preſſure of the Atmoſphere, and the Variation of that Preſſure came to be known, it appear'd that this Thermometer being affected by this various Preſſure could not truly ſhew the Degrees of Heat and Cold. In Winter, for example, the Liquor would riſe and ſink too much, and in Summer too little, as we will here ſhew. Suppoſe the Liquor at W W, and that there comes a Froſt, the Air will be condens'd ſo as to retire from W W to *w w*: now as the Air is heavier in froſty Weather, its Preſſure on the Liquor in the Veſſel C*c* will be increas'd ſo as to raiſe the Liquor a little higher in the Tube, and thereby make the Air recede to A where the Liquor will go, and there-

Plate 22. Fig. 1.

Lect. X. by shew a Degree of Cold greater than it really is. On the other hand, if the Weather grows warm, as it does in rainy Weather in Winter, the Liquor being suppos'd to stand at *ww*; the Air of the Ball, by its Expansion, will push it down to WW; but as the Weight of the Atmosphere is less in foul Weather, the Liquor in the Vessel C*c* will be less press'd than it was, and not push up the Liquor in the Tube so strongly, which Liquor descending on that account will fall to *a*, allowing the Air to expand it self so far, and shew a greater Degree of Warmth than that of the ambient Air. The Reverse of this will happen in Summer. For if you suppose the Liquor to stand at SS, when the Weather grows hot, the Air will expand it self, for example, to *ss*, to which Place it will push the Liquor in the Tube; but as warm Weather in Summer is fair Weather, the Atmosphere is then heavier than usual, and by its greater Pressure on the stagnant Liquor, it will raise the Liquor in the Tube up to E, by this accidental Pressure changing the Expansion of the Air, and shewing the Increase of Heat to be less than it really is. As in Summer the Weather grows cold in rainy Weather; let us suppose at that time the Air to be condens'd by Cold, and retiring to allow the Liquor to rise from *ss* to SS: the Weight of the Atmosphere, now that it is rainy (or foul Weather) will be diminish'd, and consequently not push up the Liquor so high in the Tube as it did before; so that it will only go up to D, to which Place the Air less compress'd will expand, and shew the Cold to be less than it really is. For this Reason the Thermometers of *Fig.* 1. and *Fig.* 2. have been disused.

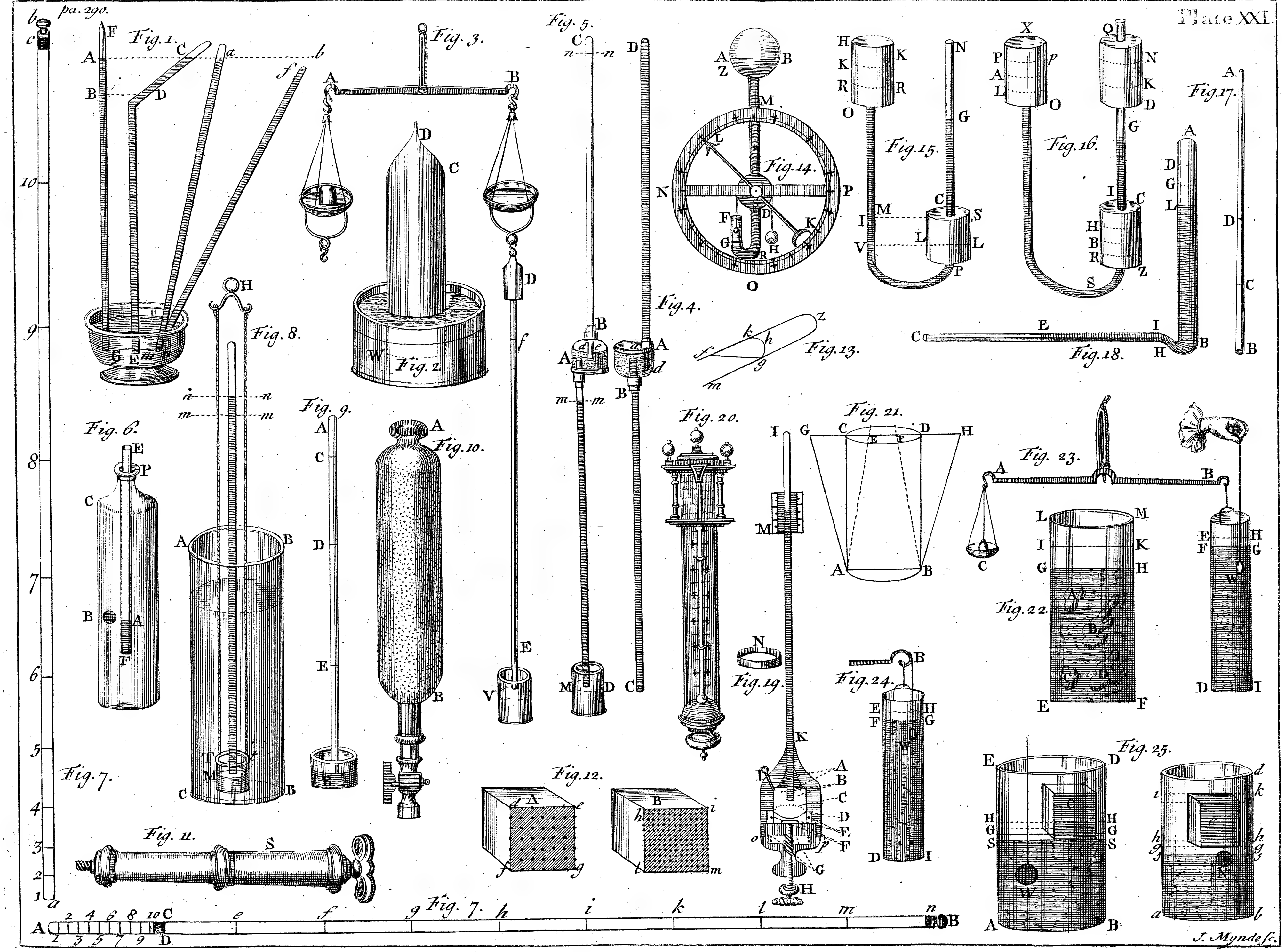
Plate 22. Fig. 1, & 2.

The Gentlemen of the *Academia del Cimento*, by the Encouragement and under the Protection of *Ferdinand* the Second, Great Duke of *Tuscany*, were the first Improvers of the Thermometer. They did no longer make use of Air; but made their Thermometers with Spirit of Wine enclos'd in Glass Tubes, and those hermetically seal'd. So that they could suffer nothing by the Evaporation of Liquor, or the various Gravity of the incumbent Atmosphere. And Thermometers made in this way were first introduc'd into *England* by Mr. *Boyle*, and came immediately to be of universal Use among the *Virtuosi* in all the several Countries, where-ever polite Learning and Philosophy were cultivated. See *Plate* 22. *Fig*. 3. But there was not so much Use made of those Instruments as they were capable of. We have plenty of Observations made with particular Thermometers at different Times and Places. But then these were not constructed by any fix'd Scale or Standard: Even the *Florentine* Weather-Glasses themselves, whose highest Term was adjusted to the greatest Sun-shine Heats of that Country, were too vague and indetermin'd. And in other Places every Workman made 'em according to his own

Plate 22. Fig 3.

pa. 290.

Plate XXI.



J. Mynde sc.

own way and fancy; without adjuſting his Numbers to any known or determin'd Degrees of Heat. And ſo they cou'd not be compar'd one with another; nor cou'd the Obſervations made by different Perſons, and in different Parts of the World, be collated with any degree of Certainty or Juſtneſs. By which means, notwithſtanding all the very numerous Regiſters of the Weather, that have been kept and publiſh'd by different Authors, we are ſtill at a loſs to determine the comparative Differences of Heat and Cold in different Countries and Climates, and the Reſult of many other Obſervations. Lect. X.

HAD all the Weather-Glaſſes in the world been made after one determin'd Scale, theſe Inconveniences and Uncertainties wou'd have been prevented; which are now unavoidable, and muſt ſtill continue ſo, until every body agrees to graduate their Thermometers in the ſame way, or at leaſt determine ſome fix'd and unalterable Points of Heat, to which all the different Scales of thoſe Inſtruments may be reduc'd.

THE way of making the Spirit-of-Wine Thermometer (*Fig.* 3.) is as follows. Take a ſmall Tube A B, as truly cylindrick as you can get one, which you may try thus: having put into one End of the Tube as much Mercury as will fill the Length of one Inch, make that Quantity of Mercury go from one Part of the Tube to another, till it has run the whole Length of the Tube, meaſuring with your Compaſſes whether it maintains its Length of an Inch in every Part of the Tube, (for it will be longer where the Tube is ſmaller, and ſhorter than an Inch where the Tube is larger;) and if it does, you may be ſure it is cylindrick, and a Scale of equal Diviſions will agree with it; (otherwiſe the Diviſions muſt be ſuited to the Contents of the Bore) then join a Glaſs Ball to the Tube, and make a ſmall Cavity as A at the other end. Fill your Thermometer with Spirits to the due Height, which you may do by inverting your Tube into a Veſſel of ſtagnant colour'd Spirit under a Receiver of the Air-Pump, or many other ways; and let us ſuppoſe the Spirit to ſtand, for Example, at M M. With a Lamp heat the little Bubble A red-hot, and ſeal it hermetically, and it will leave in the Thermometer only the third Part of the Air that was in it, which will be ſufficient to give room to the Dilatation of the Spirit: and ſo much Air is proper to be left in, as I found by an Experiment, which was this. From the Top of an Air-Pump Receiver I brought down a crooked Braſs-Pipe, to which I cemented the Tube of a Thermometer fill'd with Spirit of Wine to its due Height, and having pump'd out the Air from the Thermometer as well as the Receiver, with the Flame of a Lamp I ſeal'd the Tube of the Thermometer hermetically about 3 Inches from the Place where it was join'd to the Braſs-Pipe. I alſo took another Thermometer fill'd with Spirits to its Plate 22. Fig. 3.

Lect. X. proper Height, and by the Lamp drew the End of the Tube into a capillary Tube about an Inch long. Then putting the Ball of the Thermometer into warm Water, I rais'd the Spirit quite up into the capillary Tube within half an Inch of the End of it, and hermetically seal'd the capillary Tube with the Lamp. Then letting the Liquor fall away from the capillary Tube to its proper Distance, I mended the sealing of the Tube by melting away the capillary Tube. I thought then I had two Thermometers better than ordinary, because they had no Air in them to act against the Spirit; but then the Liquor parted in two or three Places, and cou'd not be kept together: for the Air left in the Spirit, even after the Air-Pump had been applied, by its Expansion divided the Spirit. So that I found it necessary to have a little rarified Air in the Thermometer at the end opposite to the Ball; but indeed so rare as not to become so dense as the common Air, when by the rising of the Liquor it has receeded into the little Ball A, *Fig.* 3.

If two Thermometers are fill'd with different Spirits, they cannot be adjusted to correspond by comparing together their Scales; for Example, let us call them A and B. If you find that A rises 4 Divisions, when B rises but 3; you must not expect that when A rises 8, 12, or 16 Divisions, B shall just rise 6, 9, or 12 Divisions; because the Spirit will not dilate in one, in the same proportion that it does in the other; so that unless you made the Liquor go its whole range in each of them, and new mark one at every Degree of the other, they will not be brought to correspond. Mr. *De Reaumur* being aware of this, in a very ingenious way attempted to establish a general Construction of such Thermometers, which might be copied at all Times, and in all Countries; and so to settle, as it were, a general Correspondence of Observations that should be made by such Instruments. He took a large Ball and Tube, and knowing well the Contents of the Ball as that of the Tube in every part, he graduated the Tube, so that the Space from one Division to another might contain a thousandth Part of the Liquor, which Liquor would contain 1000 Parts, when it stood at the freezing Point: then putting the Ball of his Thermometer and Part of the Tube into boiling Water, he observ'd whether it rose 80 Divisions, which, if it exceeded, he chang'd his Liquor and adding Water to it lower'd it so, that on the next Trial from the freezing Point to the Point of boiling Water it should only rise 80 Divisions: But if the Liquor being too low fell short of 80 Divisions, he raised it by adding rectified Spirit to it. The Liquor thus prepared fitted his purpose, and would serve for making a Thermometer of any size, whose Scale would agree with his Standard. Such Liquor or Spirits being of about the Strength of Brandy may be easily had any where, or be made of a proper

Degree

Degree of Density by raising or lowering it. The ingenious *Abbé Nolet*, who is a very curious Operator, and now gives Courses of Experimental Philosophy in *Paris* with great Success, has made a great many Thermometers upon Mr. *De Reaumur*'s Principle, and still makes to supply those that would make uniform Observations *. Lect. X.

* Ann. 10.

33. The late Dr. *George Martine*, whom I shall have occasion to quote by and by, finds some Faults with this Thermometer; one of which is, that the Ball or Bulb of the Thermometer being large, is not heated or cool'd soon enough to shew the quick Variations of the Weather. And indeed it is a Fault to be found with all Thermometers that have Balls to hold their Liquor; a Cylinder being much better, whatever Liquor is used; except where great Degrees of Heat are measur'd, as in Sir *Isaac Newton*'s Linseed-Oil Thermometer. For tho' most Spirit Thermometers have the Degree of the Heat of boiling Water mark'd upon them, and as one of their Boundaries; yet the Heat of boiling Water is always greater than that of boiling Spirits, and therefore they are unfit to measure that Degree of Heat. But Linseed Oil is capable of sustaining much greater Degrees of Heat; for it will bear a greater Heat than what will melt Lead without firing or having the Glass Ball of the Thermometer melted. Whereas Water is only capable of a certain Degree of Heat, much lower, at which it will evaporate; but this is only when Water boils in open Vessels †.

† Ann. 11.

34. But as I mention Sir *Isaac Newton*'s Thermometer, I think it will not be improper to give an account of the manner of making it, as I made three of them once by Sir *Isaac*'s Direction. I took a Tube of half an Inch Bore 3 Foot long, with a Ball of two Inches Diameter at one end of it, and to the Tube pasted a List of Paper in order to mark a Scale upon it. Then with a Measure containing $\frac{1}{4}$ of a cylindrick Inch, I first fill'd the Ball with Quicksilver, which contain'd 21 of those Measures; then at every Measure of Mercury pour'd into the Tube I made a Mark upon the Paper to form the Scales, finding those Marks commonly about an Inch from one another, but a little farther asunder where the Bore of the Tube was narrowest, and a less Distance than an Inch where the Bore was bigger, and for greater Exactness subdivided all these Divisions of the Scale into Decimals. Then the Mercury being well taken out of this Thermometer, Linseed-Oil was pour'd into it up to the 10th or 12th Division on the Scale of the Tube, and prepar'd in the following manner. A Crucible full of Sand being set upon the Fire, and the Ball of the Thermometer put into the Crucible so as to be quite cover'd with the Sand, first

upon

Lect. X. upon the Increase of Heat the Oil got up almost to the top of the Tube, and then it sputter'd and threw up white Fumes, whereby it parted with its Phlegm by degrees and purified the Oil; but when the white Fumes were risen above the Oil, and not out of the Tube, they wou'd sometimes stick to the Side of the Tube, where they wou'd be condens'd into Water, and run down the Tube till they came to the Ball, where by the great Heat they would make an Explosion and be shot up to the top of the Tube. In that case I catch'd these white Fumes upon Cotton fastned to a small Stick to carry it down almost to the Oil, which by this means soon ceas'd to sputter and send out Fumes, which shew'd that it was purg'd of all Moisture. Thus was the Thermometer prepar'd for Use; but in making this Operation the lower Part of the Paper-Scale was burnt off of the Glass as far as the 7th Division. We tried this Thermometer upon the following Substances, and in the following manner. Besides a Vessel of Water, we had upon the Fire four Crucibles, with these Substances in them, a Mixture of Lead, Tin, and Tin-glass (or Bismuth) in the first: in the next, a Mixture of equal Parts of Lead and Tin: in the third, Tin: and in the fourth, Lead. When we begun, our Linseed-Oil Thermometer stood at its 7th Degree, whilst the Spirit in one of *Patrick*'s Thermometers stood at the Mark of *Temperate*. Then we plung'd the Ball of our Thermometer into the Water on the Fire, where it rose beyond 9, when the Water just began to boil, but got up to 11 when the Water boil'd very much; higher than which it did not rise, tho' the Water was so heated as to boil away and evaporate very fast. Then was the Thermometer remov'd into its Crucible of Sand to be made hotter, and the Crucible containing the Mixture of Lead, Tin, and Tin-glass, was taken off the Fire and set upon the Ground. We took the Thermometer out of its Sand Crucible, and thrust its Ball into the Mixture and took it out again immediately, and this for several times till the Mixture in cooling made a Skin about the Ball of the Thermometer; and this we call'd the Degree of Heat capable of melting the Mixture. When this happen'd, the Oil which was at 20 when we took the Thermometer out of the Crucible of Sand, and at 15 when cover'd with the Mixture, was come down to $12\frac{1}{2}$. Then the Crucible of Lead and Tin mix'd was taken off the Fire, and the Thermometer (new warm'd in its Sand to secure it) was at 24 when put into this Mixture; but fell to 15 when it begun to set, as the Skin it made on the Ball of the Thermometer shew'd. The Crucible of Tin taken off at first rais'd the Oil of the Thermometer to 35; but did not begin to set till 25, the proper Heat for melting Tin. Melted Lead at first receiving the Thermometer, rais'd the Oil to 45; but began to make a Skin on the Ball, when the Oil was fallen to 35.

Care

Care muſt be taken that the Heat of the Thermometer be not a great deal greater than that of the Subſtances in which you put it, otherwiſe it will break, as I proved it with one of theſe Thermometers, which broke to pieces, when I took it out of melted Lead and plunged it into boiling Water. With this Caution there is no need of guarding the Ball of the Thermometer with Clay, as Sir *Iſaac* told me he had done. He alſo told me, that his moſt general Linſeed-Oil Thermometer, for lower Degrees of Heat, began at the freezing Point, and that the Diſtance between that and boiling Water made 34 of his Diviſions. Lect. X.

35. Of late years Quickſilver has been made uſe of for Thermometers, and they are found to be the moſt uſeful of any; becauſe they will bear ſuch Degrees of Heat or Cold as will burſt Spirit Thermometers, or freeze the Liquor in them. This laſt Inconveniency happen'd to the *French* Philoſophers who went to the North Polar Circle to examine into the Figure of the Earth; for the Spirit in their Thermometers was frozen: but their Mercurial ones were as uſeful as any where elſe. *Farenheit* of *Amſterdam* may be look'd upon as the Inventor of this Thermometer; and tho' *Prins* and ſome others, both in *England*, *Holland*, *France*, and other Countries, have made this Inſtrument as well as *Farenheit*; ſince Dr. *Boerhaave* uſed only that Thermometer, and moſt Quickſilver Thermometers are graduated according to his Scale, we may ſtill call them *Farenheit's* Thermometers.

36. There are three ſorts of Quickſilver Thermometers. The firſt or leaſt ſort, *Plate* 22. *Fig.* 4. have the Bulb in the Form of an Olive, with a Scale about the Tube or Paper which is faſten'd to the Inſtrument, and the whole ſhut up with Air in a Glaſs Tube hermetically ſeal'd. This being very portable is very uſeful, and may be put into the Mouth, or applied to any Part of the Human Body; and from below the freezing Point ſhews a Degree of Heat beyond the Blood of Animals: See *Fig.* 4. The ſecond ſort, *Fig.* 5. has its Bulb cylindrick, and reaches from *o*, which is 32 Degrees below the freezing Point, to 112 Degrees; which is below boiling Water. I have ſeen of theſe ſort of Thermometers ſo well made, and ſo well purged of Air, that when you invert them, the Mercury will run down and ſtrike againſt the ſmall End of the Tube, from whence it will return without parting, when you ſet the Tube upright again. This is fix'd to a metalline Scale, as alſo the third ſort, which is carried beyond 212 Degrees the Point of boiling Water, going quite to 600 Degrees. See *Fig.* 6. Plate 22. Fig. 4, 5. Plate 22. Fig. 6.

Lect. X.

37. To shew how much a cylindrick Bulb in Thermometers is preferable to a spherical one, take two Thermometers, fill'd with the same Spirit and graduated with the same Scale, and plunge them both at the same time in warm Water, and you'll find that the Liquor in the Thermometer with the spherical Bulb will at first fall, as from MM to H, and afterwards rise up to C, and so on; whereas the other *Fig.* 5. will not sensibly fall below D before it rises. The Cause is this; the warm Water expanding the Ball B, the Liquor having more room must descend, till being heated (which takes up time enough to make it observ'd) it rises: whereas the Liquor in the Cylinder of the other Thermometer heating immediately, hinders us from observing its Fall, on account of the swelling of the Cylinder C, which must certainly happen.

Plate 22. Fig. 5.

38. Those that wou'd know more upon this Subject must consult the late Dr. *George Martine*'s *Essays*, Medical and Philosophical, printed at *London* for *A. Millar* 1740. Where he will with great Satisfaction read the four last Essays, which treat of *The Construction and Graduation of Thermometers.* Essay 3. *The Comparison of different Thermometers.* Essay 4. *The Heating and Cooling of Bodies.* Essay 5. And *The various Degrees of Heat in Bodies.* Essay 6. In order to render useful the several Registers of the Weather, made by Observations taken with different Thermometers, I have taken from his 4th Article the Table by which he compared 15 different Thermometers, (See *Plate* 22.) Here you will find all the Degrees that have been taken of the Heat and Cold of the Weather: so that the Divisions do not rise so high as boiling Water, which was not necessary in comparing Registers of the Weather taken by several Persons in several Countries. For the Particulars relating to the several Thermometers, which I want room for here, I refer the Reader to the Essays, which are very learned and curious.

Plate 22.

The Consideration of Fire and Heat is very difficult: we know yet but very little of their nature; and I think that those Philosophers, who assert the Being of an elementary Fire, (or that Fire is contain'd in all Bodies) assume a little too much *. Whoever reads with Attention Dr. *Hales*'s *Vegetable Staticks*, will soon be of a different Opinion.

* Ann. 12.

39. The late learned and ingenious Dr. *Brook Taylor* and myself made some Experiments, whereby it appear'd to us that *actual Heat* was to *sensible Heat*, as *Motion* is to *Velocity*. That is, if a certain Quantity of Heat which warm'd (for Example) a Quart of Water, which shew'd a certain Degree of Heat on the Thermometer, was applied to warm twice

the Quantity of Water (for Example) two Quarts, the Thermometer put into this laſt Quantity of Water, wou'd ſhew but half the Heat. We deduced our Theory from the following Lect. X.

EXPERIMENTS 12, 13, 14, 15, 16.

WE caus'd two Cylindrick Veſſels of Tin holding each ſomething more than 6 Pints to be made, and fix'd in two Places of a Table 3 Iron Spikes to ſet the Veſſels, upon that Heat or Cold might not be communicated from the Table to the Cylinders, or from them to the Table. We got ſix more Cylindrick Veſſels made, but with Handles in order to take Boiling Water ſuddenly out of a large Kettle: Two of theſe Veſſels held each a Pint; the 3d, two Pints; the 4th, three Pints; the 5th, four Pints; and the 6th, five Pints. We made two ſmall Linſeed-Oil Thermometers whoſe Scales exactly agreed. The Liquor in *Patrick*'s Thermometer ſtanding at *Temperate*, our Oil Thermometers ſtood at 10 in cold Water. Then we made our Experiments in the following manner. 1°. We dipp'd one of the Pint Veſſels in the boiling Water, and emptied it in one of our large Cylinders ſtanding on the Iron Points, and in 5 Seconds the two Thermometers roſe to 16 Degrees. We dipp'd in the Kettle at the ſame time one Pint Veſſel, and the other Pint Veſſel, and pour'd the one into the empty large Cylinder as before; and the other into the other large Cylinder, in which was a Pint of cold Water, with a Thermometer in each Veſſel. In the Cylinder that had nothing but warm Water, the Linſeed Oil roſe to 16 as before; but in the other, which ſtood in the equal Mixture of warm and cold Water, the Oil roſe only to 13. Then we pour'd a Pint of hot Water ſucceſſively to 2, 3, 4, and 5 of cold Water (having cool'd the large Tin Veſſel between each Experiment) and the Oil of the Thermometer in the Mixture roſe to 12, $11\frac{1}{2}$, $11\frac{1}{5}$, and 11 Degrees. After this we pour'd 5 Pints of boiling Water to 1 of cold; 4 of boiling to 2 of cold; 3 of boiling to 3 of cold; 4 of boiling to 2 of cold; and 5 of boiling to 1 of cold: and the Oil in the Thermometer roſe ſucceſſively to 15, 14, 13, 12, and 11. Having miſlaid the Paper which gives the Particulars of this Experiment, I cannot be exact in the ſmall Diviſions or Fractions of the Numbers; but I remember that they were a little under what I ſet down; but ſo little under, that we thought the Difference of no conſequence; and fancied they might be attributed to the Heat loſt in warming the Tin Veſſel.

BUT what I depend upon moſt in this Theory, is the following Experiment made before the *Royal Society*. In a Kettle of warm Water, I had half a Pint of Water in an open Phial, and half a Pint of Mer-

Lect. X. cury in another Phial, and I let them remain half an Hour whilst the Water boil'd. Then having pour'd into a Bason half a Pint of cold Water, and into another Bason 13 ½ Pints of cold Water; I pour'd at the same time the Water from the Phial into the Bason which had the half Pint of cold Water, and the Mercury into the Bason which had the 13 ½ Pints, and in half a Minute's time the unequal Quantities of Water in the Basons were equally warm'd, as appear'd by two equally graduated Thermometers.

THERE are indeed some Experiments made by Dr. *Martine*, from which different Conclusions seem to be drawn than what Dr. *Taylor* and I drew; but upon due Consideration, it will only confine our Theory to a Fluid of the same kind: that is, the same Quantity of Heat which warms a Pint of Water will be twice more sensible, than when it is applied to warm two Pints of Water: and tho' it is certainly true, that Mercury once warm'd will communicate Heat to 13 ½ times more Water than the same Bulk of Water affected by the like sensible Heat can do; yet perhaps the Mercury may receive Heat in less time, than 13 ½ times the Bulk of Water; but I am ignorant of that, not having made the Experiment.

40. HYGROMETERS, or NOTIOMETERS, are Instruments contriv'd to shew the State of the Air as to Moisture or Dryness. There are a great many Substances fit to make Hydrometers; but none that we know of to make them lasting; that is, to keep the same Exactness for any considerable time, as a Year, for Example. I shall mention a few ways of making that Instrument. 1°. Take a fine Scale Beam, as A B, *Fig.* 7. *Plate* 22. on whose End A hang a parcel of Spunges S kept *in æquilibrio*, by a Weight, as P, hanging from the End B in any certain State of the Air: Now when the Moisture of the Air increases, the Spunges imbibing some of that Moisture over-weigh, and sink down, while their Counterpoise P rises; but if the Air become drier than it was when the *Æquilibrium* was first made, some of the Moisture evaporates from the Spunges, which then rise when the Counterpoise descends, as the Figure shews; but to make the Degrees of Moisture and Dryness the more sensible, there must be an Arc of a Circle E D fix'd to F, the Point where the Balance is suspended, having the Center of Motion of the Balance for its Center. The Beam A B must have a long Examen, or Cock, C 8, which serves for an Index to point the Degrees mark'd on the aforesaid Arc, to shew the least Alteration of the *Æquilibrium*, or Variation of A B from an horizontal Position. 2°. A second sort of Hygrometer is easily made thus: to the Bottom of a twisted hempen String hanging from

Plate 22. Fig. 7.

from H, the Cieling of a Room, fasten a Weight, as W, (*Fig.* 8.) with an Index I at its under side, and by the twisting of the String, which happens in wet Weather, the Index will point to the different Degrees of a Circle set under it, as A B. There may be a Wire perpendicularly hanging from the under-side of the middle of W, going thro' an Hole in the Center of the Circle, to keep the Index steady in its Motion. N. B. *Those* Dutch *Toys call'd Weather-Houses, where a small Image of a Man, and one of a Woman, are fix'd upon the Ends of an Index, are built upon this Principle. For the Index being sustained by a String, or twisted Cat-gut, turns backwards and forwards, bringing out the Man in wet Weather, and the Woman in dry.* 3°. But as a String not only twists, but grows shorter in wet Weather, the Hygrometer will be more sensible, by making use of a long String carried up and down from its Point of Suspension over four or five Pullies, and a Weight terminated by a broad Plate at Bottom, serving for an Index, and marking the Degrees on the Scale by rising and falling. See *Fig.* 9. where H is the Cieling Hook, P, *p*, *p*, *p*, the Pulleys, and I the graduated Scale and Index. 4°. The Beard of a wild Oat, twisting in dry, and untwisting in wet Weather, will make a sensible Hydrometer many ways. Here follows one. A B C D, *Fig.* 10. is a square Brass Plate about four Inches square, with a Ring or Circle fix'd to it, graduated on the Flat, and the inner Edge. *Fig.* 10. I C is a very light Index of Brass or Steel, having a small cylindrick Lump in its Center, into which is fasten'd the Top of the Beard of a wild Oat by a little Peg, and the other End of it in another Lump about an Inch under the Plate, which having a little Hole under C, allows the Beard of the Oat to come thro' to carry the Hand, and yet keeps it in its Place, without hindering its twisting and untwisting. There are two Wires coming down under the middle of the Plate, which hold a little cross Bar making a small Frame to carry the Lump that holds the Bottom of the Beard expos'd to the Air. The four Feet of this Instrument, two of which are seen at C, D, must be about one Inch and a Quarter long, to keep the Frame under the Plate from touching any thing that the Instrument is set upon. In *Fig.* 11. A B represents the Plate, F and F two of its Feet, C and D the little Lumps to which the wild Oat-Beard C D is fasten'd: *e f* and *g h* the hanging down Wires supporting the Piece *f h*, all together making an open Frame to hold the Lump D. *i* is the Hole in the Plate for the Beard to pass thro', as it carries the Index I *i*, which points to the Degrees on the graduated Circle A B. 5°. The last I shall mention here is an Hygrometer contriv'd by Dr. *Hales* and myself. See *Fig.* 12. P *c p w* C is a Piece of *Lignum Vitæ* cylindrick at C *w* P, but a truncated Cone from C *w* to *p*, and screw'd like the Fuzee of a Watch, but

Lect. X.
Plate 22. Fig. 8.
Plate 22. Fig. 9.
Plate 22. Fig. 10.
Plate 22. Fig. 11.
Plate 22. Fig. 12.

Lect. X. not near so taper. The Length of the Instrument is about a Foot, the cylindrick Part an Inch in Diameter, and half an Inch long. The large Part of the Screw about $\frac{3}{4}$ of an Inch, and the small Part half an Inch. There are fine Steel Pivots at each End, bearing on two fine conic Holes in Brasses in the Frame that carries the Instrument, that it may turn easily. A Spunge S hangs by a Silk from the Cylinder of the Instrument, so as to turn the Instrument by its rising or falling. A Weight W hanging from another Silk *u*, coil'd upon the Screw C*p*, keeps the Spunge *in æquilibrio*. Now when the Spunge becomes heavier by imbibing Moisture from the Air, it runs down, and draws up W; but as W comes up, its String must advance towards C *w*, where hanging farther from its Center, its Power will be so increas'd, that it will keep the Spunge *in æquilibrio*, tho' its Weight be increas'd: But as the Weight rises it will shew on the Scale D D how much the Spunge is heavier, and consequently the Air moister.

N. B. This Instrument is made very sensible, when its Pivots are supported by four Friction Wheels, such as are represented in the Friction Machine of *Vol.* I. *Plate* 18. *Fig.* 8.

41. Instead of the Spunges used in this, and the first-mention'd Hygrometer, one may put Salt of Tartar, or any other Salts, or Pot-Ash in a Scale of a Balance, which will also become heavier by attracting the Humidity from the Air, and the lighter by its Evaporation. As likewise Salts may be made use of in the Hygrometer of N° 1. Instead of the long String which goes over the Pullies of N° 3. one may make use of Parchment in a long narrow List, and it will lengthen by Moisture, and shorten by Dryness, whereas twisted Substances shorten by Moisture, while animal Substances lengthen by it. Therefore one may so combine an animal Substance with a twisted one; that is, one may make a Twist of an animal Substance, in such a manner, that Moisture or Dryness will have no effect in lengthening or shortening it; thus the Wheel-bands or Strings of some Lathes that would lengthen as they are animal Substances, (Cat-gut, for Example) shorten, as they are twisted, in moist Weather. A notable Instance of this last Effect of Weather was seen in the Machinery of an Architect, of whom the following Story is told. An Architect at *Rome* having fix'd a very high Pedestal, wanted to raise up its Obelisk, which was very heavy, to set upon it; but when he had fix'd his Machines, and hung on his Weight, and drawn it up as far as he could, his Ropes stretch'd so much, that the Obelisk could not be brought up to its necessary Height, which made the Architect fret and rage, till somebody, who had a more philosophical Head than He, bad him

him wet the Ropes; which being done, the Ropes immediately contracted, and raising the Weight up above its due Place, it was soon let down and set right. As there is scarce any Body that will not change its Dimensions by Moisture or Dryness, it would be endless to recount what Hygrometers might be made of; but it may be useful to mention what the Moisture or Dryness of the Weather can have no Influence on, and that is the straight Grain of Wood: for tho' every Door and Window in moist Weather shews us how much Wood swells cross the Grain, yet we can never find it stretch end-wise, by Heat or Cold, Moisture or Dryness. This is the Reason why that excellent Mechanick the Earl of *Ilay* makes the Rods of the Pendulums of his Clocks of Wood: and Mr. *James King*, the Carpenter for *Westminster Bridge*, combines the Pieces that make the Centers for his Arches so, that the Weather that may swell each Piece a-cross shall not lengthen those on which the Form and Bearing of his Arches depend. Lect. X.

THOSE that would know more of these Hygrometers, call'd also *Hygroscopes*, may consult the first Plate of the second Volume of *Lowthorp's* Abridgment of the Philosophical Transactions, with the Descriptions annex'd by the Authors that communicated them.

THE Hydrometers are not to be used as Weather-Glasses to fore-tell Moisture and Dryness in the Air before it comes: they only shew the present State of the Air. Neither will the same Hydrometer serve for Years, like a Barometer and a Thermometer; but will be so alter'd as to be almost useless, whatever Substance it is made of, as Professor *Muschenbroek* has well observ'd in the 699th and 700th Pages of the second Volume of his *Essays de Physique*, translated into *French* by Dr. *P. Massuet*, printed at *Leyden* 1737.

NOTWITHSTANDING this, there are many Cases wherein the Hydrometers are of great use; as, for Example, when we would see what Rarefaction the Air will undergo by great Degrees of Heat, we should know what Degree of Moisture it contains; otherwise we shall attribute to the Air what is really Rarefaction of Vapour. Thus some have thought that the Heat of boiling Water rarefied the Air ten times, some eight times, some three times, and some twice; when truly it rarefies it but $\frac{1}{3}$: but the Experiment must be made in a dry Summer, when there is no Moisture at all in the Air. And reciprocally, when we find that the Heat of boiling Water rarefies Air but $\frac{1}{3}$, and the Heat of a red-hot Retort but three times, we may be sure there is no Moisture in the Air; and mark our Hygrometer with the Point of *very dry*.

42. THERE are ſeveral Inſtruments which have been rejected on account of Defects found in them, which again came into Uſe; becauſe when thoſe Defects depend upon regular Cauſes, they may be applied to ſerve Purpoſes not thought of before. We have a remarkable Inſtance of it in the Air-Thermometer, which being join'd with the Spirit-Thermometer, ſerves to make an Inſtrument that has all the Properties of the Barometer, and really becomes neceſſary, becauſe it may be uſed when the Mercurial Barometer can't. In ſpeaking of the Air-Thermometer, we have obſerv'd that the Weight of the Atmoſphere (not known to thoſe that firſt uſed this Thermometer) interfer'd in this Inſtrument, and by its increas'd or diminiſh'd Preſſure rais'd or ſunk the Liquor of it, ſo as to make it not truly ſhew the Degrees of Heat and Cold. Now to take off this diſturbing Action of the Atmoſphere, the Spirit-Thermometer was contriv'd, ſeal'd hermetically to keep out the Preſſure of the external Air, whilſt its dilating Liquor ſhew'd only the Degrees of Heat and Cold. So that if the Preſſure of the Atmoſphere could by any means be hinder'd from acting upon the Air-Thermometer, it would be no way inferior to the Spirit-Thermometer: or which is the ſame, if one could find a means to diſtinguiſh in the Motion of the Liquor of the Air-Thermometer, what Part of it is owing to Heat and Cold, and what Part of it is owing to the various Preſſure of the Atmoſphere. Now a Means is found to do this by joining together two Thermometers, an Air-Thermometer and a Spirit-Thermometer, whoſe Difference will exactly ſhew the Preſſure of the Air, and become a Barometer.

Plate 23. *Fig.* 1.

Plate 23. Fig. 1.

IN the Frame E A C are fix'd two Thermometers, an Air-Thermometer A B, and a Spirit-Thermometer C D. The Ball B, and the Tube from B to *t* is full of Air of the ſame tenor as the outward Air: the End of the Tube goes into a little Bottle A almoſt full of Liquor, which communicates with the outward Air, by the Spout *a*, which may be ſhut up occaſionally by a ſmall Peg. The Spirit-Thermometer is hermetically ſeal'd, and fill'd with Spirits from C to T, where *temperate* is written upon the Scale of the Spirit-Thermometer, whoſe upper Ball being made red-hot before it was ſeal'd, the Air in the Ball and Tube from D to T is three times rarer than common Air, and therefore will eaſily allow the Liquor to riſe up againſt it, which it will do as the Weather grows hotter; when at the ſame time the ſame Degree of Heat affecting the Air in the Ball, makes the Liquor fall as many Degrees in the Air-Thermometer. This would always riſe juſt as much as the other fell,

fell, if there was no Alteration in the Weight of the Air. But if there was no Alteration in the Heat of the Weather, but in the Weight of the Atmosphere, it being become heavier; the Liquor in the Spirit-Thermometer wou'd remain at T, whilst that in the Air-Thermometer would rise, for Example to 1, being in that case only a Barometer, and the Space of the Liquor from 1 to 4, that is the Degrees of the Rise of the Liquor more in this Thermometer than in the other (tho' the contrary way to its Range) wou'd be proportionable to the increas'd Weight of the Air. How to adjust these Degrees to the Scale of the Quicksilver Barometer so as to represent it, will be shewn by giving you from Dr. *Halley* the Description of the Marine Barometer such as Dr. *Hooke* made for him, and he carried with him in his South-Sea Voyage. Lect. X.

43. *An Account of Dr.* Hooke's *Marine Barometer, by Dr.* E. Halley, N° 269. p. 791. *Plate* 23. *Fig.* 2. Plate 23. Fig. 2.

Dr. *Hooke*, who has made many attempts to improve the Barometer, and to render the minute Divisions on the Scale thereof, more sensible, judging that it might be of great use at Sea, contrived several ways to make it serviceable on board of Ships; one of which he explained to the Royal Society at their Weekly Meeting in *Gresham* College *Jan.* 2, 166$\frac{7}{8}$. Since which time he hath further cultivated the Invention; and some Years ago produced before the said Society the Instrument I am now to describe.

The Mercurial Barometer requiring a perpendicular Posture, and the Quicksilver vibrating therein with great violence upon any Agitation, is therefore uncapable of being used at Sea, (tho' it hath lately been contrived to be made portable.) So it remained to find out some other Principle, wherein the Position of the Instrument was not so indispensibly necessary: For this, all those that use the Sea are obliged to the great Facility Dr. *Hooke* has always shewn, in applying Philosophical Experiments to their proper Uses.

It is about 40 Years since, that the *Thermometers* of *Robert de Fluctibus*, depending on the Dilatation and Contraction of included Air by Heat and Cold, have been disused upon discovery that the Air's Pressure is unequal; that Inequality mixing itself with the Effects of the Warmth of the Air in that Instrument: And instead thereof was substituted the seal'd Thermometer, including Spirit of Wine (first brought into *England* out of *Italy* by *Robert Southwell*,) as a proper Standard of the Temper of the Air, in relation to Heat and Cold; that æthereal Spirit being of all the known Liquors the most susceptible of Dilatation and Contraction, especially with a moderate degree of

Lect. X. of either Heat or Cold. Now this being allowed as a Standard, and the other Thermometer that includes Air being graduated with the ſame Diviſions, ſo as at the time when the Air was included, to agree with the Spirit-Thermometer in all the Degrees of Heat and Cold, noting at the ſame time the preciſe Height of the Mercury in the common Barometer: It will readily be underſtood, that whenſoever theſe two Thermometers ſhall agree, the Preſſure of the Air is the ſame it was, when the Air was included, and the Inſtrument graduated: That if in the Air-Thermometer the Liquor ſtands higher than the Diviſion marked thereon, correſponding with that on the Spirit-Glaſs, it is an Indication that there is a greater Preſſure of the Air at that time, than when the Inſtrument was graduated. And the contrary is to be concluded, when the Air-Glaſs ſtands lower than the Spirit, *viz.* that then the Air is ſo much lighter and the Quickſilver in the ordinary Barometers lower than at the ſame time of Graduation.——And the Spaces anſwering to an Inch of Mercury will be more or leſs, according to the Quantity of Air ſo included, and the Smallneſs of the Glaſs Cane, in which the Liquor riſes and falls, and may be augmented almoſt in any proportion, under that of the ſpecifick Gravity of the Liquor of the Thermometer to Mercury: ſo as to have a Foot or more for an Inch of Mercury, which is another great Convenience. It has been obſerved by ſome, that in long keeping this Inſtrument the Air included either finds a means to eſcape, or depoſite ſome Vapours mixt with it, or elſe for ſome other cauſe becomes leſs elaſtick, whereby in proceſs of time it gives the Height of the Mercury ſomewhat greater than it ought; but this, if it ſhould happen in ſome of them, hinders not the Uſefulneſs thereof, for that it may at any time very eaſily be corrected by Experiment, and the Riſing and Falling thereof are the Things chiefly remarkable in it, the juſt Height being barely a Curioſity. In theſe Parts of the World, long Experience has told us, that the Riſing of the Mercury forebodes fair Weather after foul, and an Eaſterly and Northerly Wind; and that the Falling thereof, on the contrary, ſignifies Southerly or Weſterly Winds, with Rain, or ſtormy Winds, or both; which latter is of much more conſequence to provide againſt at Sea than at Land; and in a Storm, the Mercury beginning to riſe, is a ſure ſign that it begins to abate, as has been experienced in high Latitudes, both to the Northwards and Southwards of the Equator.

Plate 23. Fig. 2. AB repreſents the Spirit-Thermometer, graduated after the ſame manner with the like Degrees: *with the Spirit Ball* C, *and empty Bubble* D, (*of* Fig. 1.) *ſuppos'd behind the Board* ACB, EF is a Plate applied to the Side of the Thermometer CD, *having alſo its Liquor Bottle* A *and Air-Bubble* B (*of* Fig. 1.) *out of ſight*, graduated into Spaces anſwering to

Inches and Parts of an Inch of Mercury, in the common Barometer G, a Hand standing on the Plate at the Height of the Mercury thereon, as it was when the Instrument was graduated, as suppose here at $29\frac{1}{2}$ Inches. Lect. X. Plate 23. Fig. 2.

LM a Wire on which the Plate EF slips up and down parallel to the Cane of the Thermometer CD.

K, any Point at which the Spirit stands at the time of Observation: Suppose at 38 on the Spirit-Thermometer; slide the Plate EF till the Hand G stand at 38 on the Air-Thermometer, and if the Liquor therein stands at 38 likewise, then is the Pressure of the Air the same as at the time of Graduation, *viz.* 29,5; but if it stand higher, as at 30 at I, then is the Pressure of the Air greater; and the Division on the sliding Plate against the Liquor, shews the present Height of the Mercury to be 29 Inches 7 tenths.

I HAD one of these Barometers with me in my late Southern Voyage, and it never failed to prognostick and give early notice of all the bad Weather we had.

44. As by the sudden and quick Changes of the Pressure of the Air, when a Storm is coming (or already come) the Mercury in the common Barometer rises and falls so fast as to vibrate or dance: so likewise does it dance in the Tube by the Shake of the Ship, tho' there be no change in the Pressure of the Air, or no Storm coming; and this happens because the Attraction of Mercury to Glass is so small, that the least shake loosens it from its Contact; but when the Marine Barometer is used, the Liquor in the Air-Thermometer (which is common Water ting'd blue, with a small Mixture of *Aqua fortis* to keep it from freezing) on which the Air exerts its various Pressure (thereby shewing what happens to Mercurial Barometers) is so strongly attracted to the Inside of the Tube, which is small, that no Motion of the Ship or of the Hand which carries the Instrument, can make it dance. So that its sudden Rising and Falling can be owing to nothing but the Change of the Pressure of the Air, whereby you may be sure that a Storm is coming, and have notice to prepare for it. And this is the great use of the Marine Barometer; for tho' it may not keep exactly correspondent with the Mercurial Barometer for many Months, all we want is to shew the sudden Changes of Pressure. So that when Mr. *Patrick* the *Toricellian* Operator thought to improve this Machine by substituting Mercury instead of a lighter Liquor in his *New Marine Barometer* (as he called it) he render'd it unfit for the Sea, making it subject to receive Vibrations from the Shake of the Ship. He indeed made it a short and very portable Barometer fit always to keep pace with the common Barometer, and a new Instrument for Sale.

45. If the Air continued always to have the same degree of Heat and Cold (or what is the same thing, Heat and Cold had no influence upon the Air) then wou'd the Air-Thermometer be turn'd into a Barometer; for as the Pressure of the Atmosphere is increased or diminished, the Air in the Ball of the Instrument would be condensed, or wou'd expand it self, and let fall or raise the Liquor in proportion. Now as there are ways of keeping the Ball that holds the Air of the same degree of Heat and Cold; one may make this Machine a very sensible Barometer. I have made it so sensible, that in raising it up from the Ground to the top of a Table only three Foot higher, the Liquor has mov'd $\frac{3}{10}$ of an Inch, which is 90 times more sensible than the Mercurial Barometer, which must be carried up 90 Foot high for the Mercury to fall $\frac{1}{10}$ of an Inch. How to prepare this Machine for taking Levels (in the manner that I fitted it up when I shew'd it the Royal Society in the Year 1724, see *Phil. Transact.* N° 385,) you will find in the Notes *.

* Ann. 13.

And now I find there are still so many things to be consider'd, in order to give a full account of all the Properties of the Air, and take in the new Discoveries that have been made about it, as well as giving a Description of several Machines and Experiments to demonstrate what we have more superficially explain'd and hinted at, that this Lecture will not near contain what we have to say upon the Subject without swelling into too great a Length: therefore we must have another Lecture to finish our Pneumaticks. All that we can do now is to give our two Dissertations upon the Rise of Vapours, and Formation of Clouds and Rain, which will compleat the Doctrine of the Weather, and shew the further and full Use of the several Machines for observing it, which we have describ'd already. I must also insert my Dissertation on Electricity, that extensive Property of Bodies being a powerful Agent in several Phænomena, where it was thought to have no concern.

Phil. Transf. N° 407. *An Attempt to solve the Phænomenon of the Rise of Vapours, Formation of Clouds, and Descent of Rain. In a Letter from Dr.* J. T. Desaguliers, *LL. D. F.R.S. to Dr.* Rutty, *R. S. Secr.*

SIR,

'THE Reason of my writing upon a Subject which has been so 'often treated of, is, that none of the Accounts hitherto given 'of this Phænomenon, (at least that I have met with) seem to be suffi- 'cient to solve all the Circumstances of it.

' Dr. *Niewentyt*, and some others say——That Particles of Fire separated from the Sun-beams, by adhering to Particles of Water, make up *Moleculæ*, or small Bodies, specifically lighter than Air, which therefore, by hydrostatical Laws, must rise and form Clouds that remain suspended when they are risen up to such an Height that the Air about them is of the same specifick Gravity with themselves. Lect. X.

' That Rain is produced by the Separation of the Particles of Fire from those of Water, which last being then restored to their former specifick Gravity, can no longer be sustained by the Air, but must fall in Drops. See *Niewentyt*'s *Religious Philosopher*. Contemplation 19. from Sect. 13. to Sect. 25.

' Now this is liable to several Objections: *First*, It is built upon a Supposition that Fire is a particular Substance, or distinct Element, which has never yet been prov'd by convincing Experiments and sufficient Observations; and which the Reverend Dr. *Hales* has in his late excellent Book of *Vegetable Staticks* shewn to be an ill-grounded Opinion, making it very plain, that in Chemical Operations those Bodies which had been thought to become heavier by Particles of Fire adhering to them, were only so by Adhesion of Particles of Air, *&c.* which he has shewn to be *absorbed* in great Quantities by some Bodies whilst it is *generated* (or reduced from a *fixt* to an *elastick* State) by others; nay, that it may be *absorbed* and *generated* successively by the same Body, under different Circumstances.

' *Secondly*, If we shou'd allow the above-mention'd Supposition, the Difficulty will still remain about the Production of Rain by the Separation of Fire from the Water: For Dr. *Niewentyt* ascribes this Effect to two different Causes. *First*, to Condensation (Sect. 23.) saying, " That when contrary Winds blow against the same Cloud, and drive the watery Particles together, the Fire that adher'd to them gets loose, and they (becoming then specifically heavier) precipitate and fall down in Rain." Then in the very next *Section*, he ascribes it to Rarefaction, when he says, " That when a Wind blowing obliquely upwards causes a Cloud to rise into a thinner Air (*i. e.* specifically lighter than it self) the Fire which by sticking to the Particles of Water rendred them lighter, extricates itself from them, and ascending by its Lightness, the Water becomes too heavy, not only to remain in this thin and light Air, but even in a thicker and heavier near the Earth, and so will be turned into a descending Dew, Mist, or Rain, or Snow, or the like, according as the watery Vapours are either rarefied or compressed."

Lect. X. 'THE first of these Causes of Rain is contrary to Experience; for 'when two contrary Winds blow against each other, over any Place of 'the Earth, the Barometer always rises, and we have fair Weather. For 'then, as Dr. *Halley* says in *Philos. Trans.* N° 183. the Air being accu-'mulated above, becomes specifically heavier about the Clouds, which '(instead of falling into Rain, as Dr. *Niewentyt* supposes) ascend up into 'such a Part of the Atmosphere, as has the Air of the same specifick Gra-'vity with themselves.

'IF the falling of Rain might be attributed to the second of these 'Causes, then every time a Cloud is encompassed with Air, specifically 'lighter than itself (whether it be when by the blowing away some of 'the superior Air, that which is about the Cloud becomes rarer as it is 'less compressed, or by the Cloud being driven upwards) Rain must ne-'cessarily follow; whereas one may often see the Clouds rise and fall 'without Rains, even when the Barometer shews the Weight of the 'Air to be alter'd. For that happens only when by the great Diminu-'tion of the specifick Gravity of the Air about the Cloud, it has a great 'way to fall; in which case the Resistance of the Air, which increases 'as the Square of the Velocity of the descending Cloud, causes the 'floating Particles of Water to come within the power of each other's 'Attraction, and form such big Drops, as being specifically heavier than 'any Air, must fall in Rain.

'NO gentle Descent of a Cloud, but only an accelerated Motion 'downwards, produces Rain.

'N. B. *I don't mean that the quick Descent of a Cloud is the only 'Cause of Rain; because the Shock from a Flash of Lightning, and the 'sudden Return of the Air after the Vacuum made by the Flash, will 'condense the floating Vapour into Water; and also the same Cloud which 'in the free Air, might be carried horizontally without being turn'd into 'Rain, meeting with an high Hill in its way, will be condensed and 'fall in Drops; especially if, in the Day-time, it be driven by the Wind 'out of the Sunshine, against the shaded Side of the Mountain.*

'BESIDES all this, if Particles of Fire were join'd with those of Wa-'ter to raise them up, those igneous Particles must be at least 1000 times 'greater in Bulk than the watery ones; so that a Person, who, at the top 'of a Hill has his Hands and Face in a Cloud, must feel a very sensible 'Warmth, by touching a much greater Surface of Fire than Water in 'the Cloud, and afterwards find the Rain produced from that Vapour 'sensibly colder: whereas the contrary is prov'd by our Senses, the Tops 'of Hills tho' in the Clouds being much colder than the Rain at Bottom.

THERE

‘ There is another Opinion concerning the Riſe of Vapours, name- Lect. X.
‘ ly, that tho’ Water be ſpecifically heavier than Air, yet if its Surface
‘ be increaſed by very much diminiſhing the Bulk of its Particles, when
‘ once raiſed, it cannot eaſily fall; becauſe the Weight of each Par-
‘ ticle diminiſhes as the Cube Root of its Diameter, and the Surface to
‘ which the Air reſiſts, only as the ſquare Root of the ſaid Diameter:
‘ That we ſee this in the Duſt in Summer, and in Menſtruums that
‘ ſuſtain Metals diſſolved, which are ſpecifically heavier than the Men-
‘ ſtruums.

‘ But, this will not explain the *Phænomenon*; becauſe though the In-
‘ creaſe of Surface (the Weight remaining the ſame) will in a great mea-
‘ ſure hinder (or rather retard) the Deſcent of ſmall Bodies moving in
‘ the Air, by reaſon of its great Reſiſtance to ſo large a Surface; it will
‘ for the ſame reaſon alſo hinder the Aſcent. For the Riſe of Duſt is ow-
‘ ing to the Motion of Animals Feet in it, or to the Wind: Whereas Va-
‘ pours riſe in calm Weather, as well as windy; neither do they, like the
‘ Duſt, always fall to the ground, when the Wind ceaſes to blow.

‘ The third Opinion, and which is moſt commonly received, is, that
‘ by the Action of the Sun on the Water, ſmall Particles of Water are
‘ formed into hollow Spherules filled with an *Aura*, or finer Air highly
‘ rarefied, ſo as to become ſpecifically lighter than common Air, and con-
‘ ſequently that they muſt riſe in it by hydroſtatical Laws. As for example,
‘ if a Particle of Water, as it becomes a hollow Sphere, be only increaſed
‘ ten times in Diameter, its Bulk will be increaſed a thouſand times;
‘ therefore it will then be ſpecifically lighter than common Water, whoſe
‘ ſpecifick Gravity is to that of Air, as 850 to 1; then if the Denſity of
‘ the *Aura*, or Spirit within the little Shell, be ſuppoſed 9 times leſs than
‘ that of Air, or as $111\frac{1}{9}$ to 1000, that ſpecifick Gravity of the Shell, and its
‘ Contents will be to that of Air, as 961 to 1000; therefore ſuch an
‘ aqueous Bubble muſt riſe till it comes to an Æquilibrium in Air, whoſe
‘ Denſity is to the Denſity of that in which it began to riſe as 850 to 816,8
‘ nearly. But it appears by Experiments, that Air rarefied by an Heat
‘ which makes a Retort red-hot, is only increaſed in Bulk, or dilated 3 Times;
‘ by the Heat of boiling Water only $\frac{10}{14}$ or near two thirds; and by the
‘ Heat of a human Body (ſuch as will raiſe Vapours plentifully) only
‘ $\frac{10}{39}$, or about $\frac{1}{4}$. I own my Objection may be anſwered, by ſuppoſing
‘ the Spherule of Water to be more increaſed in Diameter, as for example,
‘ 20 times; becauſe then, if it be filled with Air only ' rarer than com-
‘ mon Air, it will be ſpecifically lighter, and capable of riſing to a conſi-
‘ derable Height.

To

Lect. X.

‘ To give this Solution all its Force, let us expreſs it in Numbers.

Plate 23. Fig. 5.

Let A and W (*Fig.* 5.) repreſent a Particle of Air, and one of ‘ Water of equal Bulk, then will the Weight of A be to the Weight of ‘ W as 1 to 850, their Bulks being equal. If the Particle of Water be ‘ blown up into a Bubble (w) of 20 Times its Diameter, then will its ‘ Bulk be to its Weight as 8000 to 850, whilſt a Sphere of Air (a) of ‘ the ſame Bigneſs, has its Weight as well as Bulk equal to 8000. Now ‘ if an Air or Aura, $\frac{1}{4}$ rarer than common Air, be ſuppoſed within the ‘ watery Bubble, to keep it blown, it will be the ſame as if $\frac{3}{4}$ of the Air ‘ of (a) was carried into (w), and then the Weight of (w) would be ‘ increaſed by the Number 6000; ſo that the Shell of Water, being in ‘ Bulk 8000, would be in Weight $850 + 6000 = 6850$, whilſt an ‘ equal Bulk of Air weighed 8000, and conſequently the watery Bubble ‘ would riſe till it came to an Air, whoſe Denſity is to the Denſity of the ‘ Air next to the Surface of the exhaling Water, as 6850 to 8000.

This is the ſtrongeſt way of ſtating the Hypotheſis. But to ſupport ‘ it, the following Queries muſt be anſwered.

‘ *Q.* 1*ſt*, How comes the Aura, or Air in the Bubbles, to be ſpeci- ‘ fically lighter than the Air without them, ſince the Sun’s Rays, which ‘ act upon the Water, are equally denſe all over its Surface?

‘ *Q.* 2. If it could be poſſible for a rarer Air to be ſeparated from the ‘ denſer ambient Air, to blow up the Bubbles, (as ſoaped Water is ‘ blown up by warm Air from the Lungs, whilſt the ambient Air is ‘ colder and denſer) what would hinder that cold Air, by its greater ‘ Preſſure, from reducing the Bubbles to a leſs Bulk, and a greater ſpe- ‘ cifick Gravity than the Air, eſpecially ſince Cold can be communicated ‘ through ſuch thin Shells, and the Tenacity of common Water is very ‘ ſmall, when compared with that of ſoaped Water, (whoſe Bubbles, ‘ notwithſtanding that Tenacity) are ſoon deſtroyed by the Preſſure ‘ of the outward Air, as the Air within them cools?

Q. 3*d*. If we ſhould grant all the reſt of the Suppoſition, yet this ‘ Difficulty will remain; if Clouds are made up of hollow Shells of ‘ Water filled with Air, why do not thoſe Clouds always expand when ‘ the ambient Air is rarefied, and preſſes leſs than it did before, and alſo ‘ ſuffer a Condenſation, as the ambient Air is condenſed by the Accumu- ‘ lation of the ſuperior Air?

‘ If this Condenſation and Rarefaction ſhould happen to the Clouds, ‘ they would always continue at the ſame Height, contrary to Obſerva- ‘ tion; and we ſhould never have any Rain.

‘ *From all this it follows, that the Condenſation and Rarefaction of the* ‘ *Vapours, which make Clouds, muſt depend upon another Principle than* ‘ *the*

'*the Condensation and Rarefaction of the Air: And that there is such a*
'*Principle, I shall endeavour to shew.*

LEMMA.

The Particles of all Fluids have a repellent Force.

'FLUIDS are elastick or unelastick: The elastick Fluids have their 'Density proportionable to their Compression, and Sir *Isaac Newton* has 'demonstrated, (*Princip. Lib.* 2. *Sect.* 5.) that they consist of Parts that 'repel each other from their respective Centers. Unelastick Fluids, like 'Mercury, Water, and other Liquors, are by Experiments found to 'be incompressible; for Water in the *Florentine Experiment* could not 'by any Force be compressed into less room, but ooz'd like Dew through 'the Pores of the hollow Silver Ball, in which it was confin'd, when a 'Force was apply'd to press the Ball out of its spherical, into a less capa-'cious Figure. Now this Property of Water and other Liquors must be 'intirely owing to the centrifugal Force of its Parts, and not its want of 'Vacuity; since Salts may be imbib'd by Water without increasing its 'Bulk, as appears by the Increase of its specifick Gravity. So Metals, 'which (singly) have a certain specifick Gravity beyond which they 'cannot be condens'd, will yet receive each other into their Interstices, 'so as to make a Compound specifically heavier than the heaviest of them; 'as is experienced in the Mixture of Copper and Tin.

SCHOLIUM.

'BY increasing the repellent Force of the Particles, an unelastick or 'incompressible Fluid may become elastick, or a Solid (at least a great 'Part of it) may be changed into an elastick Fluid; and *vice versâ*, by 'diminishing the repellent Force an elastick Fluid may be reduc'd to an 'unelastick Fluid, or to a Solid. That the Particles of Quicksilver, Wa-'ter, and other Liquors are likewise endued with an attractive Force, is 'evident from those Substances running into Drops in an exhausted Re-'ceiver, as well as in the Air, and likewise their adhering to other Bo-'dies. The Attraction and Repulsion exert their Forces differently: 'The Attraction only acts upon the Particles which are in Contact, or 'very near it; in which case it overcomes the Repulsion so far as to 'render that Fluid unelastick, which otherwise would be so; but it does 'not wholly destroy the Repulsion of the Parts of the Fluid, because it 'is on account of the Repulsion, that the Fluid is then incompressible. 'When by Heat or Fermentation (or any other Cause, if there be any) 'the Particles are separated from their Contact, the Repulsion grows

'stronger,

Lect. X. 'stronger, and the Particles exert that Force at great Distances, so that 'the same Body shall be expanded into a very large Space by becoming 'fluid, and may sometimes take up more than a million of times more 'Room than it did in a solid or incompressible Fluid. (See the *Queries* 'at the End of Sir *Isaac Newton*'s *Opticks*.) Thus is Water by boiling, 'and less Degrees of Heat, changed into an elastick Vapour rare enough 'to rise in Air, Oils and Quicksilver in Distillation made to rise in a 'very rare Medium, such as remains in the red-hot Retort, and sulphu-'reous Steams will rise even in an exhausted Receiver, as the Matter of 'the *Aurora Borealis* does in the thinner Part of our Atmosphere. If '*Aquafortis* be poured on Quicksilver, a reddish Fume will rise much 'lighter than common Air; so also will Fumes rise from Filings of Me-'tals, from Vegetables when they ferment by Putrefaction; and (as the 'Reverend Dr. *Hales* has shewn) several solid Substances by distilling, as 'well as Fermentation, will *generate* permanent Air.

'THAT Heat will add Elasticity to Fluids is evident from numberless 'Experiments, especially from Distilling and Chemistry. But what is 'needful to consider here is only, that it acts more powerfully on Water 'than common Air; for the same Heat which rarefies Air only $\frac{2}{3}$, will 'rarefy Water very near 14000 times, changing it into Steam or Vapour 'as it boils it: And in Winter, that small degree of Heat, which in 'respect to our Bodies appears cold, will raise a Steam or Vapour from 'Water at the same time that it condenses Air.

'BY a great many Observations made by Mr. *Henry Beighton*, 'F. R. S. and myself, upon the Engine to raise Water by Fire, accord-'ing to Mr. *Newcomen*'s Improvement of it, we found that the Water 'in boiling is expanded 14000 times to generate a Steam as strong (*i. e.* 'as elastick) as common Air, which therefore must be near 16 $\frac{1}{2}$ times 'specifically lighter. And that this Steam is not made of the Air extri-'cated out of the Water is plain, because it is condens'd again into 'Water by a Jet of cold Water spouting in it; and the little Quantity 'of Air that comes out of the injected Water must be discharged at 'every Stroke, otherwise the Engine will not work well. There is also 'another Experiment to confirm this.

EXPERIMENT. *Plate* 23. *Fig*. 3.

Plate 23. Fig. 3. 'A B C D is a pretty large Vessel of Water, which must be set upon 'the Fire to boil. In this Vessel must be suspended the Glass Bell E, 'made heavy enough to sink in Water; but put in, in such a manner, 'that it be fill'd with Water when upright, without any Bubbles of Air 'at its Crown within, the Crown being all under Water. As the Water

'boils,

'boils, the Bell will by degrees be emptied of its Water, being press'd 'down by the Steam which rises above the Water in the Bell; but as 'that Steam has the Appearance of Air, in order to know whether it 'be Air or not, take the Vessel off the Fire, and draw up the Bell by a 'String fasten'd to its Knob at top, till only the Mouth remains under 'Water; then, as the Steam condenses by the cold Air on the Outside 'of the Bell, the Water will rise up into the Bell at F quite to the Top, 'without any Bubble above it, which shews that the Steam which kept 'out the Water was not Air. Lect. X. Plate 23. Fig. 3.

'N. B. *This Experiment succeeds best when the Water has been first 'purg'd of Air, by Boiling and the Air-Pump.*

'We know by several Experiments made on the Fire-Engine, (in 'Captain *Savery*'s way, where the Steam is made to press immediately 'on the Water) that Steam will drive away Air, and that in proportion 'to its Heat; though in the open Air it floats and rises in it like Smoak. 'Now if the Particles of Water turn'd into Steam or Vapour repel each 'other strongly, and repel Air more than they repel each other; Aggre-'gates of such Particles made up of Vapour and Vacuity may rise in 'Air of different Densities, according to their own Density, dependant 'on their Degree of Heat, without having recourse to imaginary Bub-'bles form'd in a manner only supposed, and not proved, as we have al-'ready shewn. *I own indeed that if the watery Particles had no repel-'lent Force, they must precipitate in the same manner that Dust will do 'after it has been raised up; but we have too many Observations and Ex-'periments to leave any Doubt of the Existence of the repellent Force 'above-mentioned. Neither can I shew by any Experiment, how big the* 'Moleculæ *of Vapour must be which exclude Air from their Interstices, 'and whether those* Moleculæ *do vary in proportion to a Degree of Heat 'by an Increase of repellent Force in each watery Particle, or by a far-'ther Division of the Particles into other Particles still less; but in ge-'neral we may reasonably affirm, that the Rarity of the Vapour is pro-'portionable to the Degree of its Heat, as it happens in other Fluids,* '(*see* Phil. Transact. *Numb.* 270.) *and that though the different Degrees 'of the Air's Rarefaction are also proportionable to the Heat; the same 'Degree of Heat rarefies Vapour much more than Air.*

'Now, to shew that what has been said will account for the rise of 'Vapours, and Formation of Clouds, we must only consider;——Whe-'ther that Degree of Heat, which is known to rarefy Water 14000 * 'times,

* *As the Digression would be too long to mention here those Observations on the Fire-Engine, which shew that the Vapour from boiling Water is expanded* 14000 *times more than cold Water: I refer the Reader to the 6th Section of the 25th* Contemplation *of Nieuwentyt*'s Religious Philo-

Lect. X. 'times, being compared with several of those Degrees of Heat in Summer, Autumn, and Winter, which are capable of raising Exhalations from Water or Ice; the Rarity of the Vapours (estimated by the Degree of Heat) will appear to be such, that the Vapour will rise high enough in Winter, and not too high in Summer, to agree with the known *Phænomena*.

'*That the Effects are adequate to the Causes in this Case, I think I can make out in the following manner, viz.*

'THE Heat of boiling Water, according to Sir *Isaac Newton*'s Table (*Phil. Transact.* Num. 270.) is 34, the mean Heat of Summer 5, the mean Heat of Spring or Autumn 3, and the least Degree of Heat, at which Vapours rise in Winter (*alias* the mean Heat of Winter) is 2. The Rarity of Vapour proportionable to these four Degrees of Heat, is 14000, 2058, 1235, and 823. The Rarity of Air is, in Summer 900, in Spring or Autumn 850, and in Winter 800, the Density of Water compared with the above-mentioned Densities, being inversely as *one* to the said fore-mention'd four Numbers. The Heights above the Earth to which the Vapours will rise, and at which they will be *in æquilibrio*, in an Air of the same Density with themselves, will vary according to the Rarity of the Vapour depending on the Heat of the Season. For the Vapour which is raised by the Winter's Heat, expressed by the Number 2, when the Air's Rarity is 800, will rise to (and settle at) an Height of about the sixth of a Mile, when the Barometer is above 30 Inches high. But if the Heat be greater, then the Vapours will rise higher, and pretty much higher, if the Sun shines, though in frosty Weather, the Barometer being then very high. If the Barometer falls, and thereby brings the Place of *Æquilibrium* (for Vapours raised by the Heat 2) nearer the Earth, then also will the Heat be increas'd, the Vapour more rarefy'd, and consequently the new Place of *Æquilibrium* sufficiently high. It is to be observ'd, that in Winter, when the Heat is only equal to 2, the Air is densest close to the Earth, which has not any Heat sufficient to rarefy it near the Ground, as happens in warm Weather; therefore the Vapour will rise gradually in an Air whose Density decreases continually from the Earth upwards; neither will the Vapour be hinder'd of its full Rise, by any Condensation from a greater Cold of the ambient Air, the Air being then as cold next to the Ground where the Vapour begins to rise, as it is at any Height from the Earth.

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Philosopher, *where he proves by an Experiment made with an Æolipile, that one Inch of Water produces 13365 Inches of Vapour; which, considering the great Allowances made against the Assertion may well be call'd* 14000.

'The Vapour which is rais'd by the Heat of Spring or Autumn, express'd by Number 3, will rise to the Height of 3 ½ Miles, when the Barometer is at 30, and the Air's Rarity is 850. But then, as the Air is hotter nearer the Ground than at the Height of half a Mile or a Mile, the Vapour will condense as it rises; and as the Air, when the Earth is heated, is rarer near the Ground than at some Height from it, the Place of *Æquilibrium* for Vapour, will, upon these two Accounts, be brought much lower than otherwise it would be; as, for Example, to the Height of about a Mile, which will agree with *Phænomena*.

'In Summer, the two Causes above-mention'd increasing, the Vapour rais'd by the Heat 5, (whose Place of *Æquilibrium* would be 5 ½ Miles high, if the Vapour after it began to rise was not condens'd by cooling, and the Air was densest close to the Earth) will settle at the Height of about 1 ½, or 2 Miles, which is also agreeable to *Phænomena*.

'Lastly, as the Density and Rarity of the Vapour is chiefly owing to its Degree of Heat, and in a small measure to the increas'd or diminish'd Pressure of the circum-ambient Air, when it is not confin'd; and the Density and Rarity of the Air is chiefly owing to the increas'd or diminish'd Pressure, by the Accumulation or Exhaustion of superior Air, whilst Heat and Cold alter its Density in a much less Proportion; the Clouds made of the Vapours above-mention'd, instead of conforming themselves to the alter'd Density of the ambient Air, will rise when it is condens'd, and sink when it is rarefy'd, and also rise or sink (when the Pressure of the Air is not alter'd, and its Density very little chang'd) by their own Dilatation, owing to Heat or Cold; as may be observ'd often, by seeing them change their Height considerably, whilst the Barometer continues exactly at the same Degree, and the Thermometer's Liquor rises or falls very little, and sometimes not at all.

'As for the Manner how Clouds are chang'd into Rain, I have hinted it in the Beginning of this Paper; but for farther Satisfaction, I refer the Reader to Dr. *Halley*'s Account of it, in the *Philosophical Transactions*, (Numb. 183.) in which I entirely acquiesce, having always found it agreeable to the *Phænomena*.

'If by publishing these Thoughts I have explain'd the Rise of Vapours in a more satisfactory way than has been done before; or if I have only given useful Hints to others more capable of doing it, I have my End.

'*P. S.* Since I have for Brevity sake only mention'd at what Heights from the Surface of the Earth Vapours of different Densities will come to an *Æquilibrium*, without giving a Reason for settling the Place

Lect. X. ' of *Æquilibrium*, at those Heights; I think proper to give the Method ' here by which they are to be found, *viz.* As the Vapours will settle ' and rise where the Air is of the same Density with themselves; it is ' only required to find the Density of the Air at any distance from the ' Earth, at several Heights of the Barometer, which may be deduced ' from Dr. *Halley*'s two Tables *Philosoph. Transact.* N° 386. (the first ' shewing the Altitude to given Heights of the Mercury; and the second ' the Height of the Mercury at given Altitudes) and knowing the De-' grees of Heat by the Thermometer, because the Density of the Vapour ' depends upon the Degree of Heat of the Season; provided that proper ' Allowances be made for the great Rarefaction of the Air near the Earth ' in hot and dry Weather, and the Condensation of the Vapours in their ' Rise, by reason of the Air being colder at a little Height above the ' Earth than just at the Surface of it.'

A DISSERTATION *concerning* ELECTRICITY. *Written in the Year* 1742. *To which is annex'd, A Letter from President* BARBOT, *perpetual Secretary of the Academy of* Bordeaux, *to acquaint the Author that his Dissertation had won the Prize proposed by that Academy to be given to the Person who should write best upon that Subject.*

N. B. Every Author of a Dissertation on the Subject proposed, writes some Motto or Sentence at the bottom of his Dissertation; and also sends his Name and Titles, together with the same Motto sealed up. The Academicians first examine all the Dissertations without knowing their Authors, and when they have adjudged the Prize to any one of the Dissertations, they open the sealed Papers to find out the Author, whose Name has along with it the Motto of the Paper winning the Prize.

N. B. *FOR the sake of such Persons as are curious to know what* Electrical Experiments *have been made; those Places in the* Philosophical Transactions *of* London, *and in the* Memoires *of the Royal Academy of Sciences of* Paris, *and other Treatises concerning this Subject, are referred to, where the Experiments are described at large.*

ELECTRICITY is a Property of some Bodies, whereby they alternately attract and repel small Bodies when brought near them, and that at sensible Distances, *viz.* from a quarter of an Inch to the Distance of two or three Foot, and sometimes beyond.

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THE firſt kind of Bodies in which this Virtue or Property has been obſerved is the *Electrum* or Amber, for which reaſon it has been called *Electricity*, which Name has been retained, tho' the ſame Virtue has been obſerved in a great Number of other Bodies; as for example, in all ſorts of Glaſs, Cryſtals, and precious Stones; Reſins, Sulphurs, and ſome Minerals; dry animal Subſtances, and Vegetables (tho' rarely) but never Water and watery Fluids, moiſt Bodies, and Metals.

THE Electricity which is inherent in ſeveral Bodies is hardly perceptible, unleſs they have a vibratory Motion given to them, by Friction or any other means, ſo as to cauſe them to throw out *Effluvia* or Emanations.

I DISTINGUISH all Bodies into ſuch as are *Electricks per ſe* (or of themſelves) *and Non-Electricks per ſe*. A Body that is *electrick per ſe*, is ſuch an one in which Electricity may be excited by ſome Action upon that Body, ſuch as rubbing, patting, or warming it, and ſometimes only expoſing it to cold and dry Air after it has been covered, *&c*. A *Non-Electrick per ſe* is a Body which cannot be excited to Electricity by any Action upon the Body itſelf. But yet *Non-Electricks per ſe* receive Electricity, when you bring near them *Electricks per ſe* in which Electricity has been excited. In order to know, that Non-Electricks have received the communicated Electricity, they muſt be *inſulated*, that is, they muſt not be ſuſpended from, or ſupported by any Bodies but what are *Electricks per ſe*; for if a Non-Electrick be touched by another Non-Electrick, which touches a third, and ſo on; all the Electricity received by the firſt will go to the ſecond, and from the ſecond to the third, and ſo on, till at laſt it be loſt upon the Ground, or the Earth. But if ſeveral Non-Electricks touching one another, are at laſt terminated by Electrick Bodies, in that reſpect they make but one Body, and receive and retain Electricity for ſome time.

THERE are ſeveral ways of finding when Non-Electricks have received Electricity; (which is generally communicated to them by applying a Glaſs-Tube, excited by Friction, to one End of thoſe Bodies) of which here follow a few. If an Iron-Bar be ſuſpended horizontally by two ſilken Strings that are very dry, and the rubb'd Tube be applied or brought near to one of the Ends of the Bar, and then ſome Leaf-Gold or Leaf-Braſs, or any other light Bodies plac'd upon a ſmall Stand be brought near the other End, they will be alternately attracted and repell'd by the Bar. Likewiſe if you bring your Face or the End of your Finger near the ſaid End of the Bar; the electrical Effluvia coming out on the ſudden will make a ſenſible Pricking, with a ſnapping Noiſe, and produce a Flaſh of Light that may be ſeen in the dark. A ſmall flaxen Thread about a

Foot

Lect. X. Foot or two long, suspended by a Stick, and being brought near the Bar, will be attracted by it without destroying its Electricity till after some time. That Thread (which we shall call *the Thread of Tryal*) serves to find out when the Bar or any other non-electrick Body has receiv'd the communicated Electricity.

A Body which is *electrick per se*, does not receive this Virtue from another *electrick per se* tho' excited, till it is become a *non-electrick*; which happens when it is made moist; and then it will be made electrick only by Communication. So that an *electrick per se* may become *non-electrick*; and likewise a Body *non-electrick per se* may become electrick by Communication.

Those electrick Bodies in which it is difficult to excite Electricity, may be look'd upon as *Non-Electricks*, when their Electricity is not excited: and then they will be in the same condition as *Non-Electricks per se*, and be liable to receive Electricity by Communication in the same manner.

As there are a very great Number of electrick Bodies, which act after the same manner when Electricity has been excited in them, I shall here mention only the Tube of Glass which is rubb'd by the Hand, referring my Reader for the Enumeration of other electrick Bodies, and their Effects, to the late Mr. *Hawksbee*'s Book of Physico-mechanical Experiments, to the Philosophical Transactions of *London*, to the Memoirs of the Royal Academy of Sciences at *Paris*, and to the other Authors who have written upon this Subject.

The Glass-Tube commonly used in electrical Experiments is about three Foot and a half long, an Inch and an half in diameter, and about $\frac{1}{12}$ of an Inch thick, open at both Ends, but sometimes hermetically sealed at one End, *viz.* that which is farthest from the Hand. These Proportions are not strictly necessary: only this Bigness is most convenient for the Hand; and when the Thickness is less than $\frac{1}{12}$ of an Inch, the Electricity is sooner excited by Friction, but it does not last so long as when the Tube is thicker. You must hold the open End of the Tube (when it has one End shut) in the left Hand; and it must be rubb'd up and down several times with the right Hand, holding dry Paper or dry Cloth in your Hand: but the Hand alone is much better, provided it be very dry, which seldom happens. It is also very proper to warm the Tube a little by the Fire to dry it before you begin to rub it; but absolutely necessary to do it when the Air is moist, which is the most inconvenient Weather for making these Experiments. Dry and cold Air is the most proper, for then very little Friction is sufficient; but you must rub the

the Tube a great while, and the Electricity continues but a little while when the Weather is moist. Lect. X.

To know whether the Tube has been rubb'd long enough, and the Electricity sufficiently excited, you must strike your Fingers cross-wise near the Tube, but without touching it, at the distance of about half an Inch, and you will hear a snapping from the electrical Effluvia, which going from the Tube strike against the Fingers and rebound again to the Tube. Then you may be sure that the Tube is in a condition to produce its Effects, being fully prepar'd for making electrical Experiments; but you must not forget to rub the Tube anew (at least once) after it has been made to snap in passing the Fingers near it: because at the Place where the Fingers pass'd by and made a snapping, the Electricity of the Tube has been destroy'd. If you move your Fingers long-wise from one end of the Tube to the other (but all the while without touching it) you will hear a continued snapping, like a distant Noise of Thorns burning in a Fire. If the Room be darken'd when you make these Experiments, you will see Sparks of Light where-ever the Tube snaps; and likewise a Light following the Hand that rubs the Tube.

Some EXPERIMENTS *made with the* Tube *above describ'd, sufficient to shew the Manner in which the Bodies which are* electrick per se, *act.*

As it wou'd require a whole Volume to recount all the electrical Experiments that have been made, and those that are made every day; I shall only mention here some of the most remarkable Experiments which will serve to explain the Principles that I lay down; by which one may always certainly foretell what will happen to any Body which is excited to Electricity, or any other Body which receives the Electricity communicated from a Body in which Electricity has been excited.

EXPERIMENT I.

HAVING laid small Pieces of Leaf-Gold or Leaf-Brass, or any other small Bodies upon a little Stand whose Surface or Top was seven or eight Inches Diameter, the rubb'd Tube having been brought within a Foot or two of the Stand, the small Bodies were alternately attracted and repell'd for some time; and sometimes they were repell'd from the Tube as they were coming towards it, even before they had touch'd it, and also came back from the Stand towards the Tube without having touch'd the Stand, jumping backwards and forwards with great Swiftness.

EXPERIMENT 2.

HAVING tied a Down Feather to the top of a wooden Broach or Skewer of about six or seven Inches in Height, and fix'd upright upon a Foot; when you bring the excited Tube near it, all the Fibres of the Feather stretch out towards the Tube; but as soon as you remove the Tube, the Fibres of the Feather turn back and stick strongly to the Skewer. If you bring your Finger near to the Feather while its Fibres are tending towards the Tube, being attracted by it, the Finger will repel them; but as soon as you remove the Tube, they are attracted by the Finger. If you cover the Feather with a Glass Recipient (such as are used on the Air-Pump) that is very dry, the Tube will attract the Feather in the same manner thro' the Glass: and this happens even when the Recipient has been exhausted of its Air by the Pump. When the Tube is rubb'd near the Recipient, whether it be full of Air or empty, the Fibres of the Feather follow the Motion of the Hand along the Tube, rising and falling upon the Broach or Skewer.

EXPERIMENT 3.

WITHOUT making use of the Tube, if you rub the Recipient that covers the Feather with both Hands, the Fibres of the Feather will stretch themselves out towards the Glass like the Rays of a Sphere. If you rub but with one Hand, the Fibres will stretch themselves towards that Part of the Glass which is rubb'd: and then when you blow against the Glass, those Fibres will be repell'd notwithstanding the Interposition of the Glass: which happens also when you strike the Air with the Hand towards the Feather without touching the Recipient.

EXPERIMENT 4.

AFTER the Tube has been rubb'd, if any Assistant lets go a Down Feather in the Air at the distance of a Foot or two from the Tube, the Feather will jump towards the Tube with an accelerated Motion, and adhere to it for some time; and then of a sudden it will be repell'd from the Tube, and will fly about in the Air in such manner, that the nearer you bring the Tube to it, the more it will be repell'd, till it has touch'd some other Body; and then it will be drawn again by the Tube; which after some time will drive it away again. Sometimes when the Finger is held at eight or ten Inches from the Tube, the Feather will jump from the Tube to the Finger, and from the Finger to the Tube thirty or forty times together.

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EXPERIMENT 5.

IF a String of any kind be ſtretch'd horizontally, and from that String you hang a Thread of Silk about three Foot long and very dry, and to the lower End of that Thread you faſten a Down Feather; then at the Diſtance of about two or three Feet hang up another Feather, but by a flaxen Thread; the rubb'd Tube being brought near will attract the firſt Feather, which, when it has adher'd to it a little while, will fly from the Tube, and then be repell'd by it every time the Tube is brought near, till it has touch'd ſome other Body, as in the Fourth Experiment; and then it will be attracted anew. But the Feather which is ſuſpended by the flaxen Thread will always be attracted at the Approach of the Tube, and never repell'd. N.B. *If you wet the ſilken Thread, the Feather hanging at it will be repell'd no more, but always attracted by the Tube.*

EXPERIMENT 6.

WHEN the excited Tube is brought near your Face, you will feel the electrick *Effluvia* like ſmall Hairs which will ſtrike your Eyes and Cheeks, draw the Hairs of your Eye-brows, and make a ſmall crackling Noiſe.

EXPERIMENT 7.

IF you make uſe of a Tube which is hermetically ſeal'd at one End, and has at the other End a Braſs Ferril with a Screw, by which means you may pump out the Air from it: If you rub the Tube after you have exhauſted the Air, it does not attract any more, nor give any Light outwardly; but it gives much more Light within. Then if, by opening the Cock a little way which is faſtened to the Tube, you let in the Air ſlowly whilſt you rub the Tube, the Light diminiſhes, and being interrupted by the Air as it comes in, looks like Lightning at a Diſtance, till all the Air is come in, and then there is no more Light within; but the Light goes all to the Outſide, and the Attraction returns.

EXPERIMENT 8.

IF upon the Stand mention'd in the Firſt Experiment you ſet up edgewiſe two little Boards about nine Inches long, ſix Inches wide, and three quarters of an Inch thick (two ſmall Octavo Books will do as well) parallel to each other, and about the Diſtance of ten Inches aſunder; little Pieces of Leaf-Gold or Braſs laid upon the Stand between thoſe Boards, will not be attracted by the rubb'd Tube held near them, till it be brought quite

between

Lect. X. between the said Boards, as near to the Stand as half the Distance of the Boards from each other: that is, when the Tube is so held that a Circle describ'd round the Axis of the Tube with the Distance that is between that Axis and the Stand, passes between the Boards or Books without touching them. But when the rubb'd Tube being held horizontally at the Distance of a Foot from the Stand, seems to have no Virtue, because the Leaf-Gold has no Motion; if an Assistant snatches away the Boards all on a sudden, the Pieces of Gold will be attracted and repell'd several times, without giving any new Friction to the Tube.

Experiment 9.

When the Air is very dry, and the rubb'd Tube can attract the Leaf-Gold laid on a small Stand, to the Distance of three Foot or beyond; if the same Leaf-Gold be laid upon a Table or any large Surface, you must bring the excited Tube very near before it can produce its Effect.

Experiment 10.

When the Air is moist, the fourth Experiment does not succeed well; for after the Feather in the Air has been some time driven about by the Tube, it comes back of itself to the Tube without having touch'd any other Body; and sometimes after having adhered to the Tube towards the middle of it, it flies off of it and comes again immediately to the Tube, sticking to that Part of it which is farthest from the Hand. It happens also, when it is very dry and the Tube repels the Feather, (after having attracted it) to the Distance of two or three Foot; that if you wet the Top of the Tube at the End for the Length of six or seven Inches, the Feather will come and stick to that End of the Tube without having touch'd any other Body.

Experiment 11.

Having fill'd with Water a small Drinking-Glass of about an Inch Diameter, when you bring the rubb'd Tube near it, the Water rises in a little Hill accumulated at the Edge of the Glass, sometimes jumping towards the Tube in a little Jet, so small that you can hardly see it, tho' you may find the Tube wholly wet with it. One may also observe that this accumulated Water rises in the Shape of a small Cone whose Axis is sometimes stretch'd out horizontally towards the Tube, then snaps and falls down again flat upon the rest of the Water. If this Experiment be made in the dark, a Flash of Light accompanies the snapping.

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EXPERIMENT 12.

IF by means of an artificial Fountain (in which Air is condens'd upon the Water to make it ſpout) you play a ſmall Jet of about the 40th part of an Inch Diameter, upwards or downwards: the rubb'd Tube being brought near, the Jet will bend towards the Tube at the Diſtance of a Foot; and if the Tube be brought nearer, the Jet being wholly drawn away by the Tube, is chang'd into a Dew upon the Tube, ſo that it adheres to the Tube in little Drops, provided the Jet be not made to ſpout with too much Force.

Here follow ſome remarkable Effects of Electricity *communicated to Bodies which are* Non-electricks per ſe.

EXPERIMENT 13.

HAVING ſtretch'd horizontally a Packthread or hempen String to the Length of about twelve hundred Feet, at the End of which was ſuſpended an Ivory Ball of about an Inch and an half in Diameter; this Ball has drawn and repell'd Leaf-Braſs or Leaf-Gold when the rubb'd Tube has been brought near the other End of the String: the Thread of Trial being alſo brought near to the ſaid Ball was attracted by it.

N. B. *All the Supporters of this String muſt be* Electricks per ſe, *whether they be Hair-Ropes, Fiddle-Strings, or Cat-guts, Ribbons, Strings of Silk, Glaſs Tubes, long Bodies of Sulphur or of Reſin,* &c. and all thoſe Bodies very dry. We ſhall hereafter call the non-electrick Body, which being ſtretch'd out in length, receives the communicated Electricity, the *Conductor of Electricity*; and the Bodies on which it reſts, or from which it is ſuſpended, the *Supporters of the Conductor of Electricity.*

EXPERIMENT 14.

IF you wet the Conductor of Electricity, the Experiment will ſucceed the better; but you muſt take care not to wet the Supporters: for if the leaſt of the Supporters, for example the firſt, be wet, it becomes a *Non-electrick*, and thereby conducts the Electricity that comes to it to the Body which it touches, and from thence to the Ground, where it is loſt, not ſuffering it to go any farther upon the Conductor. If you examine the Supporters by bringing the Thread of Trial near them, you will find them to be electrick about five or ſix Inches on each ſide of the Conductor, more or leſs as the Air is more or leſs moiſt; the Supporters being as it were ſaturated with the communicated Electricity in a little ſpace near the Conductor.

EXPERIMENT 15.

If instead of stretching the Conductor at length, you carry it backwards and forwards upon the Supporters several times in parallel Lines, provided those Lines be distant enough from each other, (for example, about three Feet distant) the communicated Electricity will run as far backwards and forwards as if the String had gone streight on, and will give as much Virtue to the Ball at the End of the Conductor.

EXPERIMENT 16.

If the Conductor is stretch'd out in the Form of a Star, the electrical Virtue will be perceiv'd at all the Points of it. For example, if the Conductor be stretch'd from the first Supporter about forty Feet in length, and then divided into five Branches of twenty Feet long each, separated from each other in the manner of a Star, with a Ball at the End of each String or Point; when you bring the rubb'd Tube near the beginning of the Conductor, you will find by Threads of Trial that all the Balls have receiv'd the Electricity at the same time.

EXPERIMENT 17.

Having supported, or suspended by electrick Bodies, an Iron Bar nine Feet long, which had three Branches pointed at the End at the Distance of two Feet from each other, the Electricity communicated from the Tube at the other End, was felt at the same time by the Cheeks of three Persons which brought their Faces near the three Points, by a snapping Noise, a Pricking, and a Flash of Light seen in the dark.

EXPERIMENT 18.

Having suspended a Man horizontally (as in a swimming Posture) by two Hair Ropes, that Man becomes a Conductor of Electricity. That which he receiv'd by the Approach of the rubb'd Tube brought near the Soles of his Feet, made him strongly attract the Thread of Trial and Leaf-Brass with his Head and his Hands; and likewise with his Feet, but very weakly. But when the Tube is brought near his Head, then his Feet attract very strongly. Then if the Man (when the rubb'd Tube is brought back to his Feet) holds out his Finger near the Face of any Person standing by, a Flash of Light will fly from the Finger, a snapping Noise will be heard, and both the Man on his Finger, and the Assistant on his Cheek will feel a Pricking at the same time. In the same manner, if any one moves the Hand cross-wise near the Arms or Legs of the Person suspended, they will both feel the same Pricking: and

and if one puts an Iron Bar near the Person suspended, he will hear the Snapping, and feel the Pricking. What is remarkable, is, that if the Man hanging horizontally has on a Cloth Coat that is quite dry, you will feel no pricking when you pass your Fingers near the Coat, and the Thread of Trial will be but weakly attracted by it, nay sometimes not at all.

N. B. *Any other Animal suspended will produce the same Effect.*

Experiment 19.

The Electricity receiv'd by the Conductor advances from one End of it to the other in a kind of cylindrick *Vortex*, as may be seen by the following Experiment. Having carried a Packthread Conductor of Electricity thro' the middle of a wooden Hoop fix'd vertically upon an open Glass Cylindrick Recipient, its Plane being at Right-Angles with the Packthread: when you bring the rubb'd Tube near to one End of the Packthread, not only the Ball at its other End becomes electrick, but also the whole Circle or Hoop, tho' six Feet distant from the Ball; for the said Hoop attracts the Thread of Trial by all its Parts.

Experiment 20.

Having suspended the before-describ'd artificial Fountain, by Fiddle-Strings, and having open'd its Cock to make its Jet play, horizontally, or obliquely, or vertically upwards or downwards; if the rubb'd Tube be brought near the Body of the Fountain, the Electricity will be communicated to the whole Jet, which will then in every part of it attract the Thread of Trial; the Jet becoming then a Conductor of Electricity.

Experiment 21.

If you suspend two or three Iron Bars in the same horizontal Line, at the Distance of six Inches from one another, the Electricity communicated by the rubb'd Tube to the End of one of the Bars will go on from the one to the other quite to the End of the last Bar, where a Pricking will be felt, a Noise heard, and a Flash of Fire seen. If the Air is dry, the Electricity will jump from one Bar to another at a greater Distance; but in moist Weather the Bars must not hang above an Inch distant from each other.

Experiment 22.

Having by a Fiddle-string suspended a Bough of a Tree which had about four or five hundred Leaves, upon the Approach of the rubb'd Tube all the Leaves attracted the Thread of Trial. Then having stretch'd

Lect. X. ſtretch'd a Rope from that Bough to another ſuſpended in the ſame manner at the Diſtance of thirty Feet from the firſt: the Tube brought to one of the Boughs gave Electricity equally to the two. Afterwards ſubſtituting a very ſmall flaxen Thread, inſtead of the Rope, from one Bough to the other; the Electricity was communicated as eaſily as before.

Experiment 23.

When a ſmall String of white Silk of about the ſame Size as the flaxen Thread, was ſtretch'd from one Bough to the other, the Electricity communicated to one Bough did not go to the other: but having wet the Silk, it conducted the Electricity to the other Bough as well as the flaxen Thread.

Experiment 24.

Having mix'd Bees-Wax with about eight times its Quantity of Reſin, to hinder it from being brittle, and having melted and caſt the whole in a round Mould of about ten Inches Diameter and three Inches deep, ſpreading from the Bottom upwards, a Cake was made, which when cold appear'd to be a Body electrick *per ſe*. This Cake being warm'd, rubb'd, or patted with the Hand, attracts the Thread of Trial; and ſometimes does the ſame without any thing being done to it, but expoſing it to the Air. If you ſet this Cake on the Ground, and a Man ſtands upon it, ſtretching out his Arms horizontally, when the rubb'd Tube is applied to one of his Hands the whole Body of the Man will be impregnated with Electricity; but that Virtue will be moſt ſenſible at that Part which is moſt diſtant from the Tube, which is the Man's oppoſite Hand; to which if an Aſſiſtant bring his Face near, he will feel the Pricking, ſee the Flaſh of Fire, and hear the Snapping; the Man, render'd electrical, feeling, ſeeing, and hearing the ſame. If another Man ſtanding upon another Cake of Reſin (or a Cake made of Sulphur, or any other Subſtance that is electrick *per ſe*) at a diſtance, as for example, at thirty Feet from the firſt Man, holds in his Hand the End of a Packthread, or any other non-electrical String, of which the firſt Man holds the other End; the Electricity communicated to the firſt Man by the Application of the rubb'd Tube, will be communicated to the ſecond, who makes it be felt by thoſe that come near his Hand that is moſt diſtant from the Tube. But if the leaſt flaxen Thread falls from the Packthread, or from the Clothes of either of the Men, ſo as to touch the Ground, the Electricity will not go beyond that Thread; but running down in that Place along the Thread, is loſt upon the Ground or the

the Earth. If fifty Men ſtand upon as many electrical Cakes, communicating one with another by their Hands, or by any Non-electricks, the laſt will be ſtrongly impregnated with the Electricity that the rubb'd Tube gives to the firſt.

N. B. This has been try'd with a dozen Men; and it is not known how far this communicated Electricity may be carried.

Electricks *per ſe*, whilſt they are in a State of Electricity, can receive no communicated Electricity (or receive but very little of it at their Ends) from the Tube or other Electricks *per ſe* excited; and cannot then become Conductors of Electricity: but it is eaſy to change them into Non-electricks, and then they will become Conductors of Electricity like others.

The following Experiments *ſhew how Electricks* per ſe *become Non-electricks.*

Having ſuſpended horizontally by dry Silks a Glaſs-Tube ſix or eight Feet long, alſo very dry, at the End of which is faſten'd an Ivory-Ball, you cannot give that Ball any Electricity by applying the rubb'd Tube to the other End of the ſuſpended Tube: but as ſoon as you wet the ſuſpended Tube from one end to the other with a Spunge, that Tube conducts the Electricity, and the Ivory-Ball attracts.

Experiment 25.

As it has been ſhewn that communicated Electricity, as it is conducted, jumps from one non-electrick Body to another; it is not neceſſary that the Moiſture of the ſuſpended Tube ſhould be continuous: for after the Tube has been well dried, if you ſuſpend it anew, and find that it cannot receive or conduct any more Electricity, you need but to blow thro' it with your Mouth, and the Moiſture of your Breath will render it non-electrick, whereby it will again receive and conduct Electricity, the Ivory-Ball acting upon ſmall Bodies as before. Sometimes the changing of Bodies from electrick into non-electrick happens only by the changing of the Condition of the Air, when from being dry it becomes moiſt.

Experiment 26.

Having ſtretch'd a Packthread Conductor of Electricity to a Length of twenty Feet, upon three electrical Supporters, of which the middle one was a Stick of Sealing-wax, the Electricity receiv'd from the rubb'd Tube applied to one end of the Conductor, appear'd at the Ball ſuſpended at the other end: but when inſtead of the Ball the Stick of Wax that had been uſed as a Supporter was ſuſpended at the end of the String, the

Thread

Lect. X. Thread of Trial has not been attracted by this suspended Wax, except at its upper end joining to the Packthread; but upon wetting the Wax, it attracted the Thread of Trial strongly in all its Length. Then replacing the Ball, and restoring the wet Wax to its Place where it was before a Supporter of the Conductor of Electricity, the communicated Electricity was stopp'd at the Wax, and would go no farther till the Wax was dried.

There are Bodies which one would take for Non-electricks *per se*, because every time they are suspended by electrick Bodies, they receive (and become Conductors of) the Electricity communicated by the excited Tube: but if you dry them well at the Fire; and rub them very much, they may be made electrick. These Bodies, and those which from being strongly electrick are become non-electrick by Moisture, will indeed receive Electricity from the rubb'd Tube, and conduct it to their Ends, but in less Quantity, and do not accumulate it so strongly as the Non-electricks *per se*. This is the reason that we see less Light at the End of a wooden Bar than at the End of an Iron one; and that we hardly feel any pricking at the End of the first, tho' both have receiv'd their Electricity from the same Tube.

It has been thought that Animal Substances were electrick, and Vegetable Substances were not; because those that made the Experiments have generally succeeded in making use of Animal Substances for Supporters, and Vegetable Substances for Conductors of Electricity: but what is true in that Supposition, is only, that because Silks, Fiddle-strings, Strings of Woollen, or Hair, are very dry Substances; and Vegetables are usually moist. For if you wet those Animal Substances, they all become non-electrick, and can no more serve as Supports for the Conductors of Electricity, but will receive it when communicated, and conduct it. Likewise when the Packthread which is usually made use of to conduct Electricity very far, has been rubb'd over with Glue, and is very dry, it receives Electricity no longer, till you wet it to make it become non-electrick. A Man, or any other Animal upon a Cake of Resin, or suspended by Strings of Hair or Silk, is always non-electrick; but is only so because he always has Moisture: for when his Cloaths are dry, they are electrick *per se*, and therefore do not snap. *See the 18th Experiment.*

When we consider the different Circumstances of several Electrical Experiments, there seems to be a sort of Capriciousness, or something unaccountable in those Phænomena, not to be reduc'd to any Rule. For sometimes an Experiment which has been made several times successively, all at once will fail; or have a quite contrary Success, tho' the Circum-

stances

ſtances ſeem to be the ſame. But I hope that the Concluſions which I have drawn from the Conſideration of ſeveral principal Experiments, are ſo general, that they will ſerve as Rules to explain all the Oddneſs which ſeems to accompany the electrical Experiments, and to foretel certainly all that muſt happen in the Approaches and Combinations of Bodies in reſpect of Electricity excited, or receiv'd by Communication. Before we give Examples of the Explication of the moſt remarkable Phænomena, we muſt make mention of ſome Experiments, from which, among others, are deduc'd two other general Propoſitions to be added to what I have ſaid of Electricks *per ſe*, and of Non-electricks *per ſe*; and of the manner that the one and the other acquire or loſe Electricity.

Experiment 27.

Having ſuſpended horizontally by two ſilken Threads, about four Feet long each, a ſmall Glaſs-Tube very dry and a little rubb'd; if you apply to it long-wiſe the great rubb'd Tube, it will repel the little Tube till its Silks become inclin'd to the Horizon from being perpendicular before. Then having wet the little Tube, when you bring the great rubb'd Tube near it, it is attracted by the great Tube till its Silks are remov'd from the Perpendicular inclining near to the great Tube. From this Experiment, and many others of the ſame kind, may be concluded, that Bodies which are electrick *per ſe*, being excited to Electricity, repel all other Bodies that have Electricity; but attract them as ſoon as they have loſt their Electricity, and ſo *vice verſâ*.

Experiment 28.

Having ſuſpended a Down Feather by a ſilken Thread, as in the fifth Experiment, Sealing-wax well rubb'd produces the ſame Effect as the Tube, but more weakly, drawing the Feather; and when once it is ſeparated from the Wax, the Wax repels it continually, till the Feather has touch'd ſome other Body. But what is different here, is, that when the Feather is in a State of Repulſion in reſpect of the Wax, the rubb'd Tube attracts it; and when the Tube has given the Feather its repulſive State, then the rubb'd Wax attracts it: which ſhews that the Electricity of Glaſs is different from the Electricity of Wax. The late *Monſ. du Faye*, Intendant of the *King of France's* Gardens at *Paris*, was the firſt that obſerv'd that there are two ſorts of Electricity; and in a *Memoire* where he ſpoke of it, he ſhew'd the way of finding what kind of Electricity belongs to any electrick Body whatever.

Lect. X. To shew the Usefulness of these Rules, Laws, or Principles of Electricity, we will make use of them to explain the odd Circumstances of some Experiments: as, for example,

1°. Why don't we feel a pricking on the Eyes when the rubb'd Tube is brought near to the Face; since the Ends of the Finger of a Man made electrick, or of an Iron-Bar made electrick, makes the Face that is brought near it feel a very sensible pricking?

Answer. Because the electrical Effluvia coming from the Tube to the Face, are only those which come from that Part of the Tube which is brought near the Face; whereas the Bar gives accumulated Effluvia of the Electricity which it has receiv'd from all its Length, and from the Tube at several Applications.

2°. What is the Reason that the Feather which, having been attracted by the Tube, is separated from it, and then always repell'd till it has touch'd another Body?

Answer. Because Electricks repel one another. For which Reason the Feather, as soon as it has been impregnated with the Electricity of the Tube, is driven from it; which continues as long as the Feather keeps its Electricity, which it loses as soon as it has touch'd another Body; then being again become non-electrick, the Tube attracts it anew; thus alternately receiving and losing Electricity, it jumps several times from the Tube to the Finger, and back again. *See Experiment* 4.

3°. What is the Reason why this does not happen when the Air is moist?

Answer. Because the Feather being become electrical, draws the moist Particles that swim in the Air, and thereby losing its Electricity, is again attracted by the Tube. The Tube also at the Place which has been the least rubb'd loses its Electricity by the moist Particles which it draws out of the Air, and becoming non-electrick in that Place (as it happens when it is made wet on purpose) draws the Feather before it has lost its Electricity.

4°. Whence comes it that a Conductor of Electricity does sometimes, without changing any thing, lose its Virtue, and cease to conduct Electricity, tho' you continue to rub the Tube at one of its Ends?

Answer. Because some one of the Supports of the Conductor has imbib'd the Moisture of the Air, by which it is become non-electrick. This has happen'd to me in making use of a long Piece of Hat by way of Support, one Day that the Weather was moist. This List of Hat, having been warm'd, supported the Conductor well and effectually; but in half an Hour having imbib'd some Moisture from the Air, it stopp'd the Course

Courſe of the Electricity. When we make uſe of Glaſs-Tubes for our Lect. X. Supporters, this happens ſometimes if the Air be very moiſt.

5°. WHENCE does it happen that the Feather on the Skewer or Broach of Experiment 2. ſtretches out its Fibres, ſeparating them from each other by the Attraction of the Tube, and that the Finger repels them when the Tube is brought near to the Feather, but attracts them when the Tube is remov'd?

Anſwer. THE Fibres of the Feather extend like the Rays of a Sphere, becauſe being become electrick they repel one another. The Finger repels them becauſe it receives Electricity from the Tube; but when the Tube is remov'd, the Finger loſes its Electricity, and then it draws the Feather, which is ſtill electrical.

6°. WHENCE does it happen that in the eighth and ninth Experiments the rubb'd Tube attracts the Pieces of Leaf-Gold or Braſs much farther, when they are laid upon an *inſulated* Stand, than when they are laid upon a Table, or when they are ſhut up on two ſides upon the Stand by Books or Boards ſet edge-wiſe.

Anſwer. BECAUSE the electrical Effluvia flying off from the Tube return again in a Circle towards it, and carry with them all the little non-electrick Bodies which they meet in their way at their Return; but if thoſe non-electrick Bodies are too heavy to be brought towards the Tube, the electrical Effluvia adhering to them, and ſliding along thoſe Bodies, loſe themſelves when the Bodies are not *inſulated*, or terminated by Electricks: but when they are, the Electricity or electrick Effluvia accumulate at the Ends of thoſe Bodies which are the fartheſt from the Tube. N. B. *The Tube attracts the Feather when it is cover'd with a Glaſs Recipient, becauſe the electrical Emanations like Light (of which they ſeem to participate) eaſily penetrate electrick Bodies which do not hinder their Circulation.*

FOR want of having eſtabliſh'd Rules (that is Principles deduc'd from Experiments) by which one may explain the moſt odd *Phænomena*, People have imagin'd ſeveral Properties to belong to the Electricity of ſome Bodies, which at laſt Experience has diſprov'd. As for example, That Bodies of different Colours receiv'd more or leſs Electricity; which happen'd only becauſe when the Experiment was firſt try'd, ſome happen'd to be more or leſs moiſt than others. It has alſo been thought by ſome, that ſmall electrick Bodies ſuſpended by a fine Thread circulated round a Ball of Iron laid upon a Cake of Reſin, after the manner of the Planets round the Sun; which only happen'd becauſe the Man that made the Experiment had a great mind that the Thing ſhould be ſo, and communicated that Motion to the little Body ſuſpended without knowing that

Lect. X. he did it: for this did not happen to any other Perſon that held the Thread and pendulous Body without the ſame Inclination. The ſame may be ſaid of ſeveral other Circumſtances which are not worth mentioning.

THOUGH I have not endeavour'd to gueſs at the Cauſe of Electricity, or its Uſe in the phyſical World; not having *Phænomena* to eſtabliſh them ſufficiently, I hope to have ſatisfy'd the Gentlemen of the Academy as to what they can expect upon this Subject, in giving Rules or Principles to explain or account for the electrical Experiments that have been made hitherto, and perhaps ſuch as may be made hereafter.

YET if Conjectures are deſir'd, here follow ſome:

I SUPPOSE Particles of pure Air to be electrick Bodies always in a ſtate of Electricity, and that *vitreous* Electricity.

1ſt, BECAUSE Particles of Air repel one another without touching, as has been deduc'd from Experiments and Obſervations.

2dly, BECAUSE when the Air is dry, the Glaſs Tube rubb'd (or only warm'd) throws out its *Effluvia*, which the Air drives back to the Tube; from whence they dart out anew, and ſo move backwards and forwards with a vibratory Motion, which continues their Electricity.

3dly, BECAUSE the Feather made electrick by the Tube, and darted from it, keeps its Electricity a long time in dry Air; whereas when the Air is moiſt, the moiſt Particles which are non-electrick, floating in the Air, and being attracted by the Feather, adhere to it, and ſoon make it loſe its Electricity; which alſo happens even to the Tube in a little time.

FROM this Conſideration it will be eaſy to account for a famous Experiment of the late Mr. *Haukſbee*, which is this:——

HAVING pump'd out all the Air from a Glaſs Globe, he cauſed it to turn on its Axis very ſwiftly by means of a Rope with a Wheel and Pulley; then rubbing the Glaſs with his Hand during its Motion, there appeared a great deal of Light of a purple Colour within the Globe, without any Light or Attraction obſerv'd on the Outſide of the Glaſs, which is obſerv'd when the Air has not been pump'd out. Then turning the Cock ſo as to re-admit the Air gently into the Globe during its Motion, the Light was broken and interrupted, diminiſhing gradually, till at laſt it appear'd only on the Outſide of the Glaſs, where it was accompanied with Attraction. Does it not appear to be, that at firſt the external Air, by its Electricity, drives back the electrick Effluvia of the Glaſs, which go then to the Inſide of the Globe, where there is the leaſt Reſiſtance? For we obſerve that as the Air comes in, it repels the electrick Effluvia, that go inwards no longer when all the Air is come in. If the Fact be ſo, as the

the Experiment shews, is not my Conjecture prov'd, *viz.* that *the Air is Electrical?*

In the Reverend and Learned Dr. *Hales*'s *Vegetable Staticks*, several of his Experiments shew, that Air is absorb'd, and loses its Elasticity by the Mixture of sulphureous Vapours, so that four Quarts of Air in a Glass Vessel will, by the Mixture of those Effluvia, be reduc'd to three. Will not this Phænomenon be explain'd by the different Electricity of Sulphur and Air? The Effluvia of Sulphur being electrick repel one another: and the Particles of Air being also electrick, do likewise repel each other. But the Air being electrical of a vitreous Electricity, and Sulphur of a resinous Electricity, the Particles of Air attract those of Sulphur, and the *Moleculæ* compounded of them becoming non-electrick lose their repulsive Force.

It has for a great while been thought that watery Vapours that rise in the Air to form Clouds, used to rise, because the Water which is of itself specifically heavier than Air, (being form'd into little hollow Spherules or Bubbles fill'd with an *Aura*, or thinner Air than the ambient Air) in this new State made a Fluid of little Shells specifically lighter than the ambient Air in which it must rise like Smoke; but Philosophers are no longer of that opinion; and such as have implicitely come into it, may find it refuted in the *Philosophical Transactions*, Numb. 407.

Now may not this Phænomenon of the Rise of Vapours depend upon Electricity in the following manner?

The Air which floats at top of the Surface of the Water is electrical, and so much the more as the Weather is hotter. Now in the same manner as small Particles of Water jump towards the electrick Tube, may not these Particles jump towards the Particles of Air which have much more specifick Gravity than very small Particles of Water, and adhere to them? Then the Air in Motion having carried off the Particles of Water, and driving them away as soon as it has made them electrical, they repel one another, and also the Particles of Air. This is the reason that a cubic Inch of Vapour is lighter than a cubic Inch of Air; which would not happen if the Particles of Vapour were only carried off in the Interstices of Air, because then a cubic Inch of Air loaded with Vapour would be made specifically heavier than an Inch of dry Air; which is contrary to Experiments, which shew us by the Barometer, that Air which is moist or full of Vapours, is always lighter than dry Air.

Concerning the several AUTHORS *who have treated of* ELECTRICITY.

THE Electricity of Amber, precious Stones, and some few other Bodies, was known long ago, and has been mentioned by several Authors, such as *Gassendus*, *Gilbert*, *Digby*, Sir *Thomas Brown*, and many others; but as what has been said by many Authors that have written long ago, has been repeated by others, I shall not mention several that have spoken superficially on the Subject, and written about it when but few electrical Phænomena were known.

THE first worth mentioning particularly is Mr. *Boyle*, in whose Books you will find an account of several Phænomena of Electricity. See Dr. *Shaw*'s *Abridgement*, Vol. I. from Page 397, to Page 510.

THE next was Mr. *Francis Haukshee*, F. R. S. who made a great many new Experiments on the Electricity of *Glass*, *Amber*, *Sealing-Wax*, and several other Substances, and their Production of Light upon their Attrition in the Dark; whether *in vacuo*, or in the open Air. See his Book of *Physico-Mechanical Experiments*, printed at *London* in the Year 1709; from Page 17, to Page 69.—— From Page 109, to Page 127.—— And from Page 131, to 139.

AFTERWARDS Mr. *Stephen Gray* made several new and surprizing electrical Experiments, and pursued his Enquiries and Experiments for several Years till he died in the Year 1736: An Account of which may be found in the *Philosophical Transactions*, N° 366. N° 417. N° 422. N° 431. N° 436. N° 439. N° 441. N° 444.

MONS. *Du Faye* also made several new and curious Experiments upon this Subject, to be met with in the *History* and *Memoirs* of the *Royal Academy* of Sciences at *Paris*, for the Years 1733, 1734, and 1735; and in our *Philosophical Transactions* of *London*, in a Letter that he wrote to his Grace the Duke of *Richmond*, N° 441.

SEVERAL Persons in their Philosophical Works have quoted some of these Experiments, but none so fully as that ingenious and accurate Philosopher *Petrus van Muschenbroek*, Professor of *Experimental Philosophy* and *Mathematicks* at *Leyden*; who has written a whole Chapter about it in his *Essays de Physique*, &c. *imprimés a* Leyden *chez* Samuel Luchtmans 1739. See the 17th Chapter of his first Volume, from Page 254, to Page 272; where he gives a very particular account of most of the electrical Experiments made within these twenty Years, till the Time that he writes; except such as had not been made, or had not been published before that Time.

THE

THE rest of the electrical Experiments made since Mr. *Stephen Gray*'s Death were made by *Granvil Wheeler* Esq; mentioned in the *Philosophical Transactions* N° 253; and by myself N° 454. and N° 462; besides some others, which I lately shewed the Royal Society: An Account of which is not yet published, but will be in the *Transactions* this Winter. Indeed a few electrical Experiments, made by Mr. *Gray* and my self many Years ago, are mentioned in the First Volume of my *Course of Experimental Philosophy*, from Page 17, to Page 21.

A LETTER from President BARBOT, *&c. to Dr.* DESAGULIERS, *&c.*

'A MONSIEUR,

'MONSIEUR le Docteur *Desaguliers*, Chaplain de son Altesse Royale le 'Prince de *Galles*, Membre de la Societé Royale de *Londres*.

'*A LONDRES.*

'*Bordeaux*, 3 *Aoust* 1742.

'MONSIEUR,

'JE vous apprends avec bien de la joye que l'Academie de Bordeaux 'vient de donner le Prix à la Dissertation que vous luy avès En- 'voyée sur l'Electricité, ce qui a pour devise, *Sero sapiunt Phryges*. Cét 'avantage est d'autant plus flateur que vous l'avès remporté sur un très 'grand Nombre de Rivaux.

'COMME ce Prix consiste en une Medaille d'Or, je vous prie de char- 'ger quelqu'un a Bordeaux de la recevoir en votre Nom & d'en donner 'une quittance valable. Je suis ravy Monsieur d'étre le premier a vous 'proclamer vainqueur, j'auray l'honneur de vous envoyer des Exem- 'plaires de votre Dissertation desqu'elle sera imprimée. Je ne doute pas 'que le Public ne la lise avec le même gout que nous l'avons Couronnée. 'Vous l'avés accoutumé depuis long-temps a recevoir tous vos Ouvrages 'avec applaudissement. J'ay l'honneur d'étre avec une parfaite Estime & 'un Attachement respectueux,

'MONSIEUR,

'*Votre tres-humble & tres-obéïssant Serviteur*

'BARBOT.

Lect. X. 'Mon addresse est à Mr. le President Barbot, Secretaire perpetuel de l'Academie de Bordeaux, sur les fossés du Chapeau Rouge, à Bordeaux.'

A Dissertation *on the Cause of the Rise of Vapours and Exhalations in the Air.* By J. T. D. *LL. D. F. R. S.* &c.

THE Difficulty of the Problem concerning Vapours (or moist Exhalations) seems to consist in this; that since Water is a Fluid 8 or 9 hundred times heavier than Air, and consequently takes its place under the Air, when those two Fluids are free, how comes it to pass that Water should so expand it self as to become another Fluid lighter than the Air which is nearest to the Earth, in which it rises: and that this new Fluid having different specifick Gravities remains suspended at different Heights in the Air, according to the Air's different Densities, changing its Place with the Air, and its Height as the Air changes its Density: and yet this Fluid does not cease to be Water; as may be seen by the Formation of Rain when the Particles of Vapour or of this new Fluid reunite and fall upon the Earth, or run down the Sides of Mountains, which they meet in their Motion, and by striking against them are brought nearer together so as to be reunited into Water.

As to what relates to Exhalations (which I beg leave to call dry Vapours, or Emanations without Moisture) there is less difficulty to explain their Rise, whose Cause is pretty near, tho' not absolutely, the same, as that of the Rise of watery Vapours.

In order to explain the Phænomena of Nature, we must admit no Causes but such as really exist, and which are sufficient to produce the Effects ascribed to them: for without this, however ingenious an Hypothesis may be; he that makes it, has but only shewn how Nature may have operated, but not how it has really acted.

Tho' we should be ignorant of the Cause of the Causes whose Effects we explain, we should not reason the less justly, provided these last Causes do actually exist: and it has been an unfair Objection against the *Newtonian* Philosophers to say, that they wanted to readmit the occult Qualities of the Ancients, long exploded, by speaking of Attractions and Repulsions: because those are not really *occult Qualities*; but visible and evident Qualities, (tho' their Causes be *occult*) which produce their Effects regularly.

An

An Explication of the Principles that we shall make use of in our Dissertation, with the Proof of their Existence.

1. The Particles of Water have a repulsive Quality of immense Force.

This is prov'd, because all the Experiments that have been tried to compress Water into a less Bulk, have never been able to do it. Among other things, a Sphere of Silver has been fill'd with Water, and the Hole screwed up; then this Sphere has been powerfully compress'd with Engines to make it lose its spherical Figure, thereby to diminish its Contents, and so condense the Water: but the Water, instead of yielding to this Compression, ooz'd out thro' the Pores of the Silver in the Form of Dew. It is not for want of Interstices or Room to retire, that Water can't be compress'd; because the Dissolution of Salts in Water shews the contrary. If you dissolve in Water as much Sea-salt as it will keep melted; you may afterwards dissolve Salt-petre in it; and when it can dissolve no more Salt-petre, it will again dissolve Sea-salt to a certain degree; and then Salt-petre, again; and afterwards Sea-salt, &c. I made these Experiments till the specifick Gravity of the Water was encreas'd to a quarter; that is, till it became a quarter denser, or heavier without changing its Bulk. Thus the Waters of the Salt-Works, tho' very transparent, are very dense: at *Droitwich* in *Worcestershire* a Quart of the Water of the Salt-Springs yields half a Pound of Salt, the Brine weighing 2 *lb.* and $\frac{1}{2}$, whereas a Quart of fresh Water weighs but 2 *lb.*

All the Liquors which have Water for their Basis, are endowed with this repellent Quality. Mercury has also this repulsive Force, if an Experiment be true which has been related to me by Persons of Credit (tho' I have not tried it my self), which is, that Gold being amalgamated or dissolved in Mercury, increases the specifick Gravity of the Mercury.

Even Metals when they are in Fusion, are incompressible by this Property. We have a remarkable Example of it in Copper, which receives Tin into its Pores; so as to make the Metal compounded of these two specifically heavier than Copper, tho' much hammer'd; and tho' the Tin that is mix'd with it be $\frac{1}{5}$ specifically lighter than Copper.

2. To this repulsive Force, whose Sphere of Activity extends but a little way (perhaps not beyond the Surface of the constituent Particles of Water) succeeds an attractive Force, that we shall call *Attraction of Cohesion,* which begins where the other ends, and confines its Extent.

Lect. X. It is by this Attraction of Cohesion, which acts in a Sphere, that the Particles of Water join'd together form Drops till a certain Bigness, without the Sphere of Repulsion above-mentioned.

It cannot be said we have done wrong to give a Name to this Adhesion, since it is observ'd actually to exist.

It is owing to this Cohesion that Water rises in capillary Tubes, that Liquors rise in the Inside of Drinking-Glasses which are not full, and that in Vines and Creepers the Sap rises with Force sufficient to cleave the heavy Stones of a Building, between which they thrust their Shoots. This Force has been found sufficient to burst a Gun-Barrel by driving into dried Pease or Beans with which the Barrel had been fill'd, the Water that was put in along with them, having fix'd between the Jams of a Door, the Gun-Barrel so fill'd, to keep in the Pease. See the Rev. Dr. *Hales*'s *Vegetable Staticks*.

In respect of Water the Attraction of Cohesion does not extend farther than about $\frac{1}{12}$ of an Inch round, the biggest Drops of Water not being above $\frac{1}{6}$ of an Inch in Diameter; tho' in respect of solid Bodies to which Water adheres, the Cohesion of Water goes farther; Water being more attracted by other Bodies than by itself. Mercury is also endow'd with the Attraction of Cohesion; but in a different manner from Water; because Mercury attracting Mercury more than it does Water, does not rise in capillary Tubes; but on the contrary, when you put down into a Glass Vessel of Mercury a small capillary Tube $\frac{1}{12}$ or $\frac{1}{8}$ of an Inch under the Surface of it, (provided the Bore of this capillary Tube be not above the 40th of an Inch) the Mercury will lie lower in the Tube, than the Surface of the Mercury in the Vessel, being attracted out of the Tube by the Mercury below it.

It is also by this Attraction of Cohesion that Mercury adheres to all Metals, except Iron.

3. When the Particles of Water are separated by any Cause whatever that puts them into motion, the Attraction of Cohesion yields by little and little, and acts no longer at a distance something sensible; and then a second repellent Force may succeed to the Attraction of Cohesion; and the Particles acquire a Force, (which in this case we shall call *centrifugal*) by which they repel each other, and fly off even to very great Distances, oftentimes taking up 14 thousand times more Space than when they were join'd in Water. This will happen by the Action of that Degree of Heat which makes Water boil; the Water being then chang'd into a Vapour, whose Elasticity is equal to that of the Air, whilst its Density is 16 times less than the Density of the Air. This has been prov'd by those that have examin'd the Operations of the Engine made

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use of in *England* to drain Mines, by raising Water with the Force of Fire. Lect. X.

When Fire produces the Effect which I have mention'd on the Water, the Heat is that of boiling Water; but when you increase the Fire, the centrifugal Force of the Particles of the Vapour or Steam is also increas'd, so as to give the Steam a Spring seven or eight times greater than that of Air; as I have often made the Experiment.

4. This fluid Vapour, (which is not a dilated Air separated from Water, as has been shewn by a very sensible Experiment: See *Philosoph. Transact.* N° 407. but is entirely made up of Particles of Water) owing its centrifugal Force entirely to the Heat, loses it by Degrees, as the Heat diminishes; and when the Heat of the Vapour or Steam is so abated as not to exceed the Heat of the external Air; this Fluid, which acted so strongly by its Spring, loses it entirely, its great Bulk diminishes, its Parts come together again, and it becomes Water, as it was at first. This is evident by the working of the Fire-Engine; for when the Steam of the boiling Water has been let into the great Cylinder to raise the Piston moving in it against the whole Weight of the Atmosphere, and it has produc'd its Effect; a Jet of cold Water is let in among the Steam, which destroying its Heat, makes it lose its Spring; and immediately its Particles which have lost their centrifugal Force come together again, and adhering by the Attraction of Cohesion, fall to the Bottom of the Cylinder in the true Form of Water, leaving the rest of the Cylinder empty of Air, and of Steam or Vapour: and this Operation is perform'd 14 or 15 times in a Minute.

5. To shew yet another way that the Bulk of Vapours diminishes, as the Heat abates, we need only observe the Smoak which goes out of the Top of the Chimneys in foul Weather, when the Air is light, (as the Mercury falling in the Barometer shews it.) Then you see the Smoak (which is only a moist Vapour driven from the Wood or Coal by the Fire) descends again as soon as it is come out of the Funnel of the Chimney, instead of rising, as it does when the Air is serene and heavy. The reason of this is, that whilst the Vapour was in the Funnel of the Chimney, it kept its State of Rarefaction by the Heat which remain'd in the Funnel, and rose in the Air, having less specifick Gravity than the Air; but that Heat not being continued beyond the Funnel, the Vapour loses of its Bulk, and becoming specifically heavier than the Air, descends in it, and returns towards the Earth.

6. Air is a Fluid, whose Parts are endow'd with a centrifugal Force, whereby they repel each other without touching.

Lect. X. TAKE a Glass Tube of about $\frac{1}{4}$ Inch Bore, and six Feet long, which being recurv'd at the End, rises perpendicularly and parallel to the longest Leg to the Height of about one Foot and two Inches. The end of this short Leg must be seal'd hermetically, and that of the long Leg open'd. Pour Mercury into this Tube till it rises up two Inches in each Leg, and you'll find that the Air contain'd and shut up in the lower Leg will be a Foot high. Pouring in more Mercury into the long Leg, till it comes up to the Height of 30 Inches, the Air in the short Leg will be condens'd into a Space of six Inches, and follow'd by the Mercury, which will rise up to that Height. If you pour still more Mercury into the Tube to the Height of 30 Inches more, (in all 60 Inches) the Air will retire into a Space of four Inches, the third Part of the Space which it took up before it was compress'd by any Height of Mercury.

IF you incline the Tube so that the Column of Mercury of 60 Inches may not have its upper end above 30 Inches perpendicular higher than the Air shut up in the short Leg of the Tube, the Air will dilate itself into a Space of six Inches, proportional to the Action of the Mercury which compresses it, acting only according to its perpendicular Height. From this it follows, that the Density of the Air is proportional to the Force that compresses it: and Sir *Isaac Newton* has demonstrated, that a Fluid thus condition'd consists of Parts that have a centrifugal Force; that is, which repel each other from their respective Centers. Sir *Isaac Newton* has also made Experiments, from which it follows, that the Particles of Air do not touch one another; for having shewn that Fluids have two kind of Resistances, the one according to the Quantity of Matter which a Solid moving in a Fluid has to displace, (which Resistance is proportional to the Square of the Velocity of the Solid) and the other, which proceeds from the Tenacity of the Fluid, (that is, of the Parts which are entangled one in another, and which also in touching attract each other) which Resistance is as the Velocity itself; he has found by many Experiments of blown Bladders falling in the Air from an Height of 272 Feet, that Air had not this last Resistance, the Resistance of the Air at every Experiment being only as the Square of the Velocity. See *Newton*'s *Princ. Math. Lib.* 2. *Sect.* 7.

7. THE Atmosphere or Air which encloses our Earth, is a Compound of several kinds of Vapours and Exhalations, that come out of several solid and fluid Bodies, and continue to be suspended and float about in the Air, no longer than the centrifugal Force of their Parts continues; for every compressible Fluid that loses the centrifugal Force of its Parts, (and consequently its Elasticity) ceases to be a Fluid, and becomes a Solid.

I CALL *pure* or *permanent Air*, that Part of the Atmoſphere whoſe Particles have naturally a centrifugal Force, which is ſupported or ſuſtain'd by no Agent on which its Augmentation or Diminution depends. This Property of the Particles of the Air extends uniformly from the Earth to the greateſt Height the Air is ſenſible at, and gives the Air its Spring, which is always of the ſame Strength where the Air's Denſity is the ſame; for the Spring of the Air only increaſes with its Denſity, which depends upon its Compreſſion. Hence it happens that the Air which is neareſt to the Earth is the moſt denſe, and has the greateſt Spring, becauſe it is compreſs'd by all the ſuperior Air; and in receding from the Earth, the Air's Denſity or ſpecifick Gravity diminiſhes, as it has leſs ſuperior Air to compreſs it. Lect. X.

YET we muſt obſerve here, that in warm Weather (and eſpecially in thoſe Countries where the Soil is very dry) the Air is not denſeſt next to the Ground; becauſe the Heat of the Sun reflected from the Surface of the Earth acts upon the Air to a certain Height, which makes the heated Air receive an Increaſe of centrifugal Force, whereby its Parts repelling each other more ſtrongly, it increaſes its Rarefaction ſo as to ſuſtain the ſuperior Air as ſtrongly as if it was more denſe, during the time that the Heat continues to act: ſo that the denſeſt Part of the Air will then be above the Surface of the Earth at the cold Region of the Air, where the Heat ceaſes to act.

IF you ſhut up ſome of this Air in a Veſſel, having try'd its Spring and ſpecifick Gravity; you will find after ſeveral Years, that it keeps thoſe Properties entire; and even if it be condens'd in a Wind-gun, we ſhall find that it has loſt nothing of its Spring after a conſiderable time; for it has been found in the ſame Condition after 16 Years.

THE Vapours and Exhalations that float in the Air do not extend themſelves upwards like pure Air; but form Clouds which remain in the Air ſuſpended at different Heights according to their different ſpecifick Gravities, which depend upon the different Cauſes which have given or reſtor'd the centrifugal Force to their Particles. Theſe Clouds keeping ſtill the ſame Denſity, are carried about here and there by the Winds without changing their Height, whilſt the ambient Air that ſuſtains them keeps the ſame ſpecifick Gravity; but when that Air becomes more denſe by the Accumulation of ſuperior Air, the Clouds riſe up till they come to the Place where the Air has the ſame, and no greater ſpecifick Gravity than the Clouds: then if a Part of the ſuperior Air being carried off, the Air about the Clouds rarefies or dilates itſelf, as it is freed from Part of the Weight that it ſuſtain'd, the Clouds deſcend again down to the Place of their *Æquilibrium*, which they find where the Air is of the

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Lect. X. same specifick Gravity with them: and all this may happen without Rain, whose Formation we shall consider hereafter.

8. THERE is a surprizing Paradox in Nature; which is, that the same Particles which have a centrifugal Force by which they repel one another, have at the same time a great Force of Attraction in respect of other Particles, which other Particles repelling each other make a Fluid of another kind. This Attraction of Cohesion, whether from one Fluid to another, or from Fluids to Solids, does very much exceed mechanical Forces or Pressions. This is prov'd by many chemical Experiments. For example, Liquors which could not be compress'd by any Force apply'd outwardly, are chang'd into Solids by the Mixture of other Liquors: Metals that resist strongly, and keep their Tenacity under great Strokes of Hammers, lose it entirely, and are dissolv'd by the Attraction of acid Spirits.

9. WHEN Fire, or a very great Heat, acts powerfully enough upon Sulphur to overcome the Attraction of Cohesion which holds together its finest Parts, those Parts separate, and repelling each other become sulphureous Exhalations, which (tho' they repel each other with Force enough to make a very light Fluid which rises very high, even where the Air is extremely rare) yet have an attractive Force in respect of the Air, by which they often destroy the repellent Force of the Air, losing at the same time their own mutual repellent Force. By this means are form'd little Lumps or Moleculæ having no Elasticity, which fall to the Earth, having lost the repellent Force which made them fluid, either consider'd as Air, or as sulphureous Exhalations. The Reverend and Learned Dr. *Hales* has made several Experiments by burning Brimstone Matches in Recipients full of Air, and the sulphureous Effluvia have commonly absorb'd a Quarter of the Air contain'd in those Vessels. The aërial Particles thus join'd to the sulphureous Particles will sometimes produce Moleculæ so big that they can no longer go into the small Vesicles of the Lungs, and by that means become unfit for Respiration. This perhaps is the reason why People have been suddenly kill'd by Lightening, without receiving any Wound, the Air becoming suddenly pernicious for Respiration, by the Mixture of a subtil Sulphur.

THE most pure and permanent Air, which Moisture and Dryness can change no otherwise than by increasing or diminishing its Density, loses all its Elasticity by these sulphureous Exhalations; and there are also several Bodies which attract the Air so strongly, that it loses its Elasticity, and becomes a kind of Cement, which holds together the Parts of the Bodies to which it adheres. Dr. *Hales* says of those Bodies, that they *absorb* Air. This fix'd Air thus join'd to Bodies sometimes separates from

them by Fermentation, and then he says that they *generate* Air. There are several Bodies which contain much Air, whose Elasticity is unactive, being overcome by a stronger Attraction; but in distilling those Bodies, the Air extricates itself from them by the Force of Fire. This Air does no way differ from common Air, having all its Properties. Lect. X.

10. WHEN Air attracts moist Vapours, whose Particles adhere to those of the Air, it only loses its Elasticity in part; and at last it disengages itself from those watery Particles, which it repels after having attracted them, and then they repel each other, having, as it were, receiv'd their repellent Virtue from the Air. This Property of the Air is what I call its *Electricity*.

11. To prove that Air is *electrical*, I must here mention some electrical Experiments, out of a great many that have been made in *France*, *England*, and *Holland*, *&c.*

WHEN it is very dry Weather, whether in Summer or Winter, if we rub with a dry Hand a Glass Tube of an Inch and ½ Diameter, and about two or three Feet long; a Down Feather let loose in the Air is drawn by the Tube, and comes to it with an accelerated Motion; and having stuck to the Tube a little while, it is repell'd again from it with great Force, and floats in the Air, being driven about by the Tube, which cannot be brought near the Feather till after some solid Body (not electrical) has been brought to the Feather; which is immediately attracted by it, and then it returns again to the Tube that attracts it a-new, and presently repels it again. Thus the Feather jumps several times from the Tube to the other Body, and from the Body to the Tube alternately. But if instead of the said Body you hold towards the Feather another Tube rubb'd like the first, it drives away the Feather without touching it, and the two Tubes repel it equally.

WHEN two Persons make the Experiment with two Feathers, when each of the Feathers has been attracted by its Tube, and repell'd from it, these Feathers repel each other, whether they be set a-floating in the Air, or suspended by two very dry silken Threads. But if one of the suspended Feathers has not been touch'd by the Tube, and the other has, this last will go towards the first, attracting, and being attracted by it.

THESE Experiments do not succeed in moist Weather; for then the Feather having been driven away by the Tube into the Air, is again attracted by it after a little time, and sometimes falls to the Ground wholly inactive. Rubbing the Tube a-new to excite its Electricity a-fresh, which is weaken'd, the Feather may be repell'd; but that Virtue lasts but a little while.

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Lect. X. By theſe Experiments, and a great many others, we ſee that electrick Bodies (whether they be ſo naturally, or whether they are become electrick by Reception of Electricity from another Body) repel one another all the time that they keep their Electricity.

When the Air is very dry, very little Friction excites a Glaſs Tube to Electricity, and the Virtue laſts a great while; becauſe the electrical Emanations being repell'd by the Air, return to the Tube, and from the Tube fly back into the Air making a great many Vibrations. After the ſame manner alſo the Down Feather, when the Tube has made it electrick, is repell'd by the Air, and keeps its Electricity a great while. Whereas when the Air is moiſt (for ſometimes the Air is loaded with Humidity, even to half its Bulk, and ſometimes it is perfectly dry) the Feather being become electrical by the Action of the Tube, attracts the Particles of Vapour which float in the Air, and in a little time loſes its Electricity; which is the reaſon that the Tube attracts it a-new, as if it had touch'd ſome other viſible Body.

The Particles of Water are attracted by electrick Bodies, not only when they are ſeparated from each other in the form of Vapours; but they are even drawn off from a ſmall Jet d'Eau at a Diſtance ſenſible enough; nay, they are ſometimes ſeparated from the reſt of the Water in a Veſſel full of it, (when you bring near the Water a Glaſs Tube excited to Electricity) by a Force greater than the Coheſion of the Particles, becauſe it overcomes it without any Aſſiſtance of Heat; ſince the Experiment ſucceeds very well when it freezes hard.

12. We have now a ſufficient number of Facts and Obſervations upon Experiments, to deduce from thence the Explication of the propos'd Phænomena; that is, to ſhew in what manner the Vapours and Exhalations riſe in the Air. But before we begin, it will not be amiſs to take off the Prejudice in favour of an Opinion commonly receiv'd by a great many Philoſophers, otherwiſe very ingenious Men.

13. They imagine that watery Vapours conſiſt of an Aſſemblage of ſmall Bubbles of Water, each of which is ſpecifically lighter than Air; becauſe tho' the Skin which forms each Bubble be heavier than an equal Bulk of Air, they ſuppoſe that the Inſide of the Bubble is fill'd with an *Aura* or Air much more rarefy'd than the external Air, and that thus the Thinneſs of what is in the Bubble making amends for the Weight of its outward Skin, little Spherules are form'd, each of them lighter than an equal Bulk of Air; and that thus the Vapours riſe by hydroſtatical Laws, like the Bubbles of ſoap'd Water blown by Children, which float a conſiderable time in the Air. But it is not enough to ſuppoſe ſuch Bubbles which might riſe in the Air, if they did exiſt: one muſt alſo ſhew

ſhew by what Mechaniſm they may be produc'd. When People blow up Balls of ſoap'd Water, the Air of the Lungs which ſwells up thoſe Spheres being warm'd, is always lighter than the external Air, ſo that when thoſe Balls are thin enough, they may very well ſwim in the Air, and even riſe in it: but as ſoon as the Air of the Balls is cool'd as much as the outward Air, thoſe Bubbles of ſoap'd Water never fail of falling to the ground. The Reſemblance of Bubbles of ſoap'd Water to the imaginary Bubbles of Vapour, is all the Foundation of this Hypotheſis; but a mechanical Explication of the Production of the Bubbles of Vapour ſhould be given. The Maintainers of it ſhould tell us how the Air which reſts upon the Water ſeparates itſelf into two Parts, the one very warm, and the other cold; and ſhew how the warm Air blows up the Particles of Water into Bubbles, whilſt the reſt of the Air being cold acts outwardly, and deſcending with more Force than the Bubbles, cauſes them to riſe. The Abſurdity of this Suppoſition is ſo plain, that it is not neceſſary to ſay any more about it by way of Confutation. Lect. X.

HERE follows the Manner in which I think the Vapours are rais'd.

14. CONSIDERING the Particles of Water to be ſpherical, (which the Particles of all Fluids are ſuppoſed to be) it is certain that thoſe that form the Surface of the Seas, Rivers, and Lakes, *&c.* touch one another in fewer Points than thoſe which are below the Surface, and conſequently that their mutual Coheſion being weaker, it is eaſier to ſeparate them from one another, than thoſe which are below the Surface. So that the ſame Degree of Heat which might act within the Water without ſeparating its Particles, is capable of ſeparating them when it acts upon the Surface: but for the Evaporation there is more requir'd than a bare Separation; there muſt be a mutual repellent Force: for without that, the Vapour, tho' rais'd by the Motion, would not remain in its State of a Fluid ſpecifically lighter than Air to riſe yet higher, and form Clouds; but the Particles would re-unite; and, being reduc'd to Water, fall to the Earth, or into the Water from whence they have been ſeparated: for in the Receiver or Cylinder of the Engine to raiſe Water by Fire, this happens when an Injection of cold Water is made among the Steam or Vapour; that injected Water being no colder than the outward Air: and yet it diminiſhes ſo much the Heat which ſuſtained the centrifugal Force of the Particles of Water, as to hinder them from repelling one another; but on the contrary they come to attract one another. And this would happen to the Particles of Water which riſe in Vapour in the open Air, if Heat was the only Agent. But the Air which cannot enter into the

Lect. X. Cylinder of the Fire-Engine, acts here, drawing to it all the small Particles of Water by its Electricity, which joining to the Particles of Air are carried off by the Air. The Air by degrees communicates Electricity to the watery Particles, which it repels again as soon as they are become electrical; and then those Particles repel each other (as all electrick Bodies do) and form a Fluid which being lighter than Air rises in the Air, where it continues at different Heights according to its specifick Gravity, and that of the Air in which it is inclosed, whose Density is proportionable to the Quantity of the superior Air by which it is compressed.

These Vapours keep their repellent Force a long time, and lose it only by great Shocks which happen to them by a *precipitated Fall*, when there is a great and sudden Diminution in the Density of the Air in the Place where they are; and that falling by an accelerated Motion, they find a great Resistance to their Descent in proportion to the Square of their Velocity in the Air: because the inferior Air in that case striking or pushing the Clouds upwards, their Particles are brought near enough for the Attraction of Cohesion to take place, so as to make them join again into Drops of Water. I said *precipitated Fall*, because when the Density of the Air in which the Clouds float is but a little diminish'd, so that they have but a little way to descend to come to their *Æquilibrium*, they descend without producing Rain; as may be observ'd when the Mercury in the Barometer falls but slowly.

15. As to Exhalations, (or dry Vapours) it is not necessary that they should receive Electricity in order to have a repellent Force; because it commonly appears that they are electrick of themselves. When we rub Sulphur, Amber, Resin, Sealing-Wax, *&c.* or Glass and precious Stones, electrical Effluvia's fly out of them. Thus also Particles that are separated from Vegetables, Animal Bodies, Minerals, and even from Metals, by Distillation, Fermentation, Putrefaction, or the Action of acid Spirits, repel one another immediately and rise in the Air, having so much the more repellent Force, as they had attractive Force in the solid Bodies from whence they came before their Separation.

16. This therefore is our System concerning the Rise of Vapours and Exhalations. But lest it should not appear to all our Readers to be sufficiently established, we shall relate two remarkable Experiments from the Rev. Dr. *Hales* above-mention'd, which confirm what we have said, concerning the Action of the Electricity of Air. As Gun-powder is commonly dried by the Heat of a Plate of Iron made red-hot; Dr. *Hales* has found out a way less dangerous, which has dried the Powder as well.

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He has made common Air (without heating it firſt) to go thro' a certain Quantity of Gun-powder; and the Powder by that means has been dried as effectually, as it is at any time by the hot Plate of Iron. He has likewiſe made an Experiment with Hops, driving freſh Air thro' a great Quantity of them, by which means they were as well dried as if they had been dried in a Kiln, as they uſually are. Theſe two Experiments ſhew that Air carries away along with it the Moiſture of Bodies: and as theſe Experiments were made in Summer, when the Air is found to have no Moiſture; it follows that the Air which attracted the watery Vapours of the Powder and of the Hops, threw them off again in a little time, and thoſe Vapours becoming a Fluid of its kind, turn'd to Clouds that riſe very high when the Air is dry and heavy. Lect. X.

17. For a further Confirmation of our Opinion, one may obſerve, that wet Linnen, and all moiſt Bodies dry ſooner, and Ponds and Veſſels of Water evaporate more, in windy, than in calm Weather, tho' it be much hotter when there is no Wind; becauſe the Air which is next to the wet Bodies, and the Surface of the Waters does not remain long in the ſame place, but drawing aqueous Particles by its Elaſticity, carries them off, giving place to other Air, which ſucceeds it very quick; and by that means the Evaporation is more abundant: without taking notice of what is obſerv'd by all the World, *viz.* That two Hours of Wind dry dirty Streets more than two Days of fair Weather without Wind.

To end this Diſſertation, we ſhall anſwer ſome Difficulties and Objections, which might be made againſt our Syſtem.

1. If it be aſked, why the Vapour of boiling Water or Steam, which having acted ſtrongly by its Spring in the Cylinder of the Engine to raiſe Water by Fire, is condens'd again, or returns to Water by the Injection of a Jet of cold Water: and yet the Steam of boiling Water in an open Place does not fall again when it is riſen up the Height of ſome Feet in the Air, where the ambient Air is at leaſt as cold as the Jet of cold Water which has condens'd the Steam in the Cylinder of the Engine? We anſwer, that the Steam or Vapour of the Water boiling in a Place expos'd to the open Air, does indeed acquire a centrifugal Force in its Particles, which it loſes again when it has riſen ſome Feet by the Action of the ambient Air; but then the Air by its Electricity draws thoſe watery Particles, which being ſeparated from one another are in a better Situation to yield to the electrical Attraction of the Air, and to receive an electrical Virtue by Communication, which they do in an Inſtant, and

Lect. X. being immediately thrown off from the Particles of the Air, the repellent Force of the Electricity succeeding to the repellent Force that they had received before from the Action of the Fire, they continue a long time a rare and elastick Fluid, forming Clouds and rising till they come to their Place of *Æquilibrium* in the Air. Whereas in the Fire-Engine, where the Air does not come in among the Steam (nay there is even a contrivance with a Valve to discharge the Air which comes in with the Water at each Jet, call'd by the Workmen *the snifting Clack*) when the Steam or Vapour has left its Heat it condenses again into Water; which will happen even without making a Jet in the Cylinder, as the Cylinder and the contain'd Steam grows cold, tho' more slowly.

2. How comes it to pass that Air, which is 8 or 900 times specifically lighter than Water, can raise up great Quantities of it? Why is it not sooner attracted by the Water, absorb'd, and plung'd into its Substance? To this we answer, that the constituent Particles of Air have more specifick Gravity or Density than those of Water. The different Kinds of Air which make up our Atmosphere, come from the different Exhalations of solid Bodies, of Metals, of Minerals, of Animals and Vegetables, and thence proceed the different Sorts of Air. Now all the Bodies that produce it are specifically heavier than Water, as is immediately seen in respect of all the Bodies except the Vegetables, which one wou'd think to be specifically lighter than Water, because Wood swims in Water; but, if you open well the Interstices of Wood, by boiling it, or keeping it long under Water, (even Cork it self) it becomes specifically heavier than Water, so that the Particles of which the Air is compounded are much heavier than those of which Water is compounded, which separate from it to become Vapour. For this reason the Particles of Air may carry off the Particles of Vapour, without making a Compound specifically heavier than Air. Besides that, a very moderate Degree of Heat puts the Particles of Water in a condition to be attracted by Air, separating them much more from one another than it does the Particles of Air. It is known by Experiment, that a Degree of Heat (for example, that which is sufficient to boil Water) which changing Water into Vapour, increases its Bulk 14 thousand times, producing a Fluid above 16 times rarer than Air; is not capable to increase the Bulk of Air above one third.

3. If it be true (by N° 9.) that the Particles of the sulphureous Exhalations joining with those of Air compound little inactive Moleculæ, which precipitate; whence comes it that aqueous Particles do not do the same with Air? Answer. As the repellent Force of Exhalations and

Vapours acts more or less strongly, according as their Attraction was greater or less in the Bodies from which they separated; so when they meet with Particles that they attract, they adhere with more or less Force accordingly. This is the reason why the watery Particles when they adhere to the Particles of Air, have not attractive Force enough to destroy the whole repulsive Force or Elasticity of the Air.—— I was going to say Electricity; for I believe that at last it will be found that those Terms are synonymous in respect of Fluids. The watery Particles are also smaller than the sulphureous Particles; for when they are join'd to the Particles of Air, they can easily enter into the Vesicles of the Lungs, since one may breathe them without much Difficulty, tho' with some Inconveniency. Lect. X.

4. Lastly, If it be ask'd why should we look for two Causes of the Elevation of Vapours, *&c?* Could not one sufficient Cause be found? Does not Nature act always in the most simple manner?——I answer, that the Fact is so; and secondly, that final Causes seem to require it. For without Heat, Air might perhaps have carried off the Vapours; but they are prepar'd by Heat, and would not have been transparent without it, as may be seen towards the End of Summer when the Days grow short: whereas when it is very warm, the Sky appears of a fine blue, tho' the Vapours rise in great quantity; for the little Corpuscles of Water become invisible, when their visual Angle subtends less than a Minute of a Degree, of which the Eye is the Center.

P. S. I forgot to observe that it is not foreign to the present purpose to take notice here that the late Monf. *Du Faye* observ'd, that there were two Sorts of Electricity, and that Bodies which are endow'd with one Sort of Electricity attract those which are endow'd with the other Sort of Electricity, whilst they repel those which have the same Electricity. He calls the one the *resinous* Electricity, and the other the *vitreous* Electricity; and the Experience of others confirms what he has asserted upon that head. There are Phænomena relating to Vapours and Exhalations, which may be explain'd by those Considerations. As for example, sulphureous and fuliginous Exhalatious, are of a *resinous Electricity*; and the nitrous and tartarous Exhalations as also the Particles of Air have the *vitreous Electricity.* Hence it comes that sulphureous Exhalations attracting the nitrous, come together with great Force, and produce so great a Fermentation that they enflame with Lightnings and Explosions.

By this means several pernicious Exhalations precipitate, or destroy one another.

Lect. X. IT happens also that the Air, which loses much of its Elasticity, and becomes inactive by the Attraction of sulphureous Exhalations when it is shut up with them, does not lose so much when it is free and moveable; because aqueous Vapours, tho' repell'd by the Air, are attracted by the sulphureous Exhalations, which by this means Moisture hinders from corrupting the Air, *&c.*

——— *depressa resurgo.*

ANNOTA-

Annotations upon the Tenth Lecture.

1. [9.——*Air pressing on a Man*, &c.——*weighs* 32153 *Pounds six Ounces Averdupoids at a Mean.*]

If we wou'd know how much the Pressure of the Air is upon the whole Surface of the Earth, we must imagine it to be cover'd with Water to the Height of 33 Feet, which will give a Shell or hollow Sphere of Water that Thickness, whose Surface contains 201 Millions and 136 Thousand square Miles; for if we take the Diameter of the Earth to be in round Numbers 8000 Miles, the Circumference will be 25142 Miles, which Numbers multiplied by each other will give 201136000 square Miles for the Surface of the Earth, or of the Watery Shell; for tho' the Outside of the Shell is something too big, the inner Surface will compensate for it, the Diameter of the Earth by which we found that Surface having been taken a little too great.

The reason why People are apt to think the Air light in fair Weather, when it is really heavy, is because when the Barometer is at near 31 Inches, the additional Weight of about 3000 ℔ of Air is like a Bandage all over our Bodies, which renders our Flesh firm and contracting our Blood-Vessels, the Blood driven out by the Heart at every Systole, must move faster than when our Blood-Vessels are wider; which making our Circulation brisker, we feel light and alert, and fancy the Air to be lighter. Whereas in foul cloudy Weather 3000 ℔ Weight of Air being taken off from pressing us, our Flesh becomes flabby, our Blood-Vessels dilating by their own Spring afford a larger Passage to the Blood driven from the Heart, the Circulation becomes languid; and because we feel a Heaviness, we think the Air to be heavy, and fancy it to be loaden with Vapours, whereas the Vapours are lighter than an equal Bulk of clear Air.

2. [15.——*Letting in the Air at top*——*treated algebraically in the Notes.*] This is to find readily how much the Air will be rarefied by a Suspension of some Mercury in a Tube.

Let the Length of the Tube A B be call'd a;

The Height of the Mercury in the Barometer B D $= b$;

Consequently you will have A D $= a - b$;

Let the Quantity of Air of the same Tenor as the Atmosphere be AC $= c$;

Let the Space which must be occupied by the same Air, after the Mercury is fallen by making the Experiment, be A E $= d$;

In this manner the Mercury has then in the Tube the Height B E, which is equal to $a - d$, and D E is to A E — A D $= d - a + b$. The Weight of that Column of Mercury D E is properly the same, which makes Æquilibrium

Annotat. Lect. X. brium with the elastick Force of the Air left in the Tube, whence it happens that the Air is compressed by that Weight. Consequently the whole Weight of the Air BD $= b$: is to DE $= d - a + b$ :: as the Space taken up by the Air at AE $= d$, is to that which the Air took up before at AC $= c$. Therefore when c is unknown, you find $c = \frac{dd - ad + bd}{b}$; and if d be unknown, you have $d = \sqrt{bc + \frac{1}{4}aa + \frac{1}{4}bb} + \frac{1}{2}a - \frac{1}{2}b$; and if b be unknown, you have $b = \frac{dd - ad}{c - d}$; or if a be unknown, you have $a = d + b - \frac{bc}{d}$.

3. [18.—*Mr.* Orme *of* Ashby, *&c.*] See the Description of his Barometer in the *Philosophical Transactions*, N° 448.

4. [20.——*We must determine the Proportion that there is between the Difference of the Height of the Columns of Mercury——done in a little Compass algebraically in the Notes.*]

Plate 21. *Fig.* 15.

LET us call a the Diameter of the Cylinders OH and PC, and d the Diameter of the Tube CN, the Weight of the Atmosphere will consequently be $VK - \frac{LG}{14}$; thus likewise we have $MR = RI - \frac{SN}{14}$. The Water which in the lower Cylinder fills the Space LS, rises in the Tube to the Height GN; consequently, as the Square of the Diameter of the Cylinder PC, is to the Square of the Diameter of the Tube CN :: so is the Height GN, to the Height LS, that is $aa : dd :: GN : LS$, therefore LS is $= \frac{ddGN}{aa}$, which is also equal to KR. The Column RI is $= VK - 2KR$, and instead of KR taking its Magnitude found $\frac{ddGN}{aa}$, you will have $RI = VK - \frac{2ddGN}{aa} + \frac{SN}{14}$, which is also equal to $\frac{2ddGN}{aa} - \frac{LG}{14} + \frac{SN}{14}$. The Column $SN - LG$ is equal to $GN - LS$, for they are both together $= 0$, because SN is $= LG$, and $GN - LS$; if therefore instead of LS you set down the Quantity found, you will have $SN - LG = GN - \frac{ddGN}{aa}$: these Quantities must be placed instead of the Difference found, and then you will have $\frac{2ddGN}{aa} + \frac{GNaa - ddGN}{14aa} = \frac{2ddGN}{aa} + \frac{SN - LG}{14}$.
Now if this be work'd according to the usual Rules of Algebra, you will have $\frac{28ddGN + aaGN}{14aa}$, equal to the Height of the Mercury, which represents the Difference of the Weight of the Atmosphere, when the Water is at G, and afterwards at N; but the Ratio of the Height of the Water GN to the Height of the Mercury, to which it is equal, is as GN to $\frac{28ddGN + aaGN}{14aa}$, so

that

that dividing the whole Sum by GN, and multiplying by $14\,aa$, you will have $14\,aa$, to $28\,dd + aa$. Annotat. Lect. X.

5. [23.——*Mr.* Caswel—— *his Barometer's Description*—— *and Calculation seen in the Notes.*] This being describ'd in *Philos. Transact.* take in the Professor's own Words.

Part of a Letter from Mr. Caswell *Astronomy-Professor of* Oxford, *F. R. S. to the Rev. Mr.* Flamstead, *M. R. S. S. giving an account of a new Baroscope, invented by him, and communicated by Mr.* Hodgson, *F. R. S.*

'SIR,

'I Have made a new sort of Baroscope, 'tis cheap and very exact; I here 'send you its Calculation, as it occurred to my Thoughts before I made 'it. Suppose A B C D * is a Bucket of Water, in it the Baroscope $xrezy$ 'osm, which consists of a Body $xrsm$, and a Tube $ezyo$; the Body and 'Tube are both concave Cylinders communicating with each other, and made 'of Tin (for want of Glass:) The Bottom of the Tube zy has a Lead-weight 'to sink it, so that the Top of the Body may just swim even with the Sur-'face of the Water by the addition of some Grain-Weights on the top. 'The Water when the Instrument is forced with its Mouth downwards gets 'up into the Tube to the Height yu. There is added on the top a small 'concave Cylinder, which I call the Pipe, to distinguish it from the bottom 'small Cylinder, which I call the Tube. This Pipe is to sustain the Instru-'ment from sinking to the bottom, md is a Wire, ms, de are two Threads 'oblique to the Surface of the Water, which Threads perform the Office of 'Diagonals: For that while the Instrument sinks more or less by the Altera-'tion of the Gravity of the Air, there where the Surface of the Water cuts 'the Thread, is formed a small Bubble, which Bubble ascends up the Thread 'while the ☿ of the common Baroscope ascends.

* Plate 23. Fig. 4.

'THE Circumference of the Body is 21 Inches, therefore its Area $= 35$: 'the Altitude $ms = 4$, therefore the Body's Solidity $= 140$, each Base xm, 'rs, has a Convexity, whose Altitude is 0.65, therefore the Conoid on each 'Base is nearly $= 11\frac{1}{2}$, therefore d the whole Body is $= (140 + 11\frac{1}{2} + 11\frac{1}{2} =)$ 163 and b the entire Altitude of the Body $= (4 + 0.65 + 0.65 =)$ 5.3. The inward Circumference of the Tube is 5.014, therefore its 'Area $n = 2$. the Length of the Tube $= 4.5$, therefore the Tube's Capa-'city $= 9$, therefore C, the Content of the Body and Tube $= 163 + 9 =$ '172 Cubick Inches, that is almost $2\frac{1}{2}$ Quarts.

'SUPPOSE the Air's Pressure when greatest $=$ 30.5 Inches of ☿ $= (30.5 \times 14 =)$ 427 of Water, and $f = 427$, therefore $fc = 73444$. Put a for 'the Depth ou of the Air in the Tube when the Body is just all immersed; 'the Air in the Instrument on Immersion contracts somewhat by the Cold of 'the Water: This Contraction I find is nearly as much as would be produced 'by the Addition of 1 Inch to the Atmosphere's Altitude 427; this in cold 'Weather, but in warm Weather 'tis probably twice as much: but we will

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'now suppose it = 1, therefore the Depth of the Surface of the Water in 'the Tube below the Surface of the outer Water is $= b + a$, therefore the 'Pressure on that inner Surface is as the Altitude of the Atmosphere above 'it $= f + b + 1 + a = F + a$ (putting $F = f + b + 1$.)

'Then for that the Spaces into which the Air is contracted, are reciprocal 'to their respective Pressures, and for that while the Instrument is out of the 'Water the Pressure f answered to the Space C, therefore $F + a : f :: C$: '$\frac{fc}{F+a} =$ Space which the Air takes up in the Instrument under Water; 'therefore, $\frac{fc}{F+a} - d =$ that Part of the Tube which is possess'd by Air $=$ 'an (supposing the Tube's Area $2 = n$). Therefore $fc - fd - ad = Fan$ '$+ aan$. Therefore $aa + \overline{F + \frac{d}{n}} \times a = \frac{fc - Fd}{n}$. Put $F + \frac{d}{n} = 2g$, 'therefore $aa + 2ga = \frac{fc - Fd}{n}$ therefore $a = \sqrt{:\frac{fc - Fd}{n} + gg} - g$.

'Then suppose the Atmosphere's Gravity less, so much as to sink the ☿ '$\frac{1}{10}$ Inch = 1.4 of Water, and therefore putting $\varphi = F - 1.4$, and in the 'last Equation α instead of a, and γ instead of g, you have $\alpha = \gamma\, \frac{fc - \varphi d}{n}$ '$+ \gamma\gamma : - \gamma$. Thus I find $\left.\begin{matrix} a = 2.72, \\ \alpha = 2.94, \end{matrix}\right\}$ and therefore $\alpha - a = .22$, which .22 '$\times n$, gives .44 cubick Inches, and (supposing a Cube Inch = 253 Grains) 0.44 '$\times 253 = 111$ Grains—Weight of Water that was got up into the Tube in the 1st 'Case more than in the 2d; and therefore the Baroscope requires an Addition 'of 111 Grains on its Top to sink it with the Level of the Water in the 2d Case 'more than in the first, and this upon the sinking of the ☿ in the common 'Baroscope only $\frac{1}{10}$ Inch. Now 1 Grain in this new Baroscope is nearly as 'discernible as $\frac{1}{10}$ Inch in the common; and therefore this new Baroscope is 'more exact than the common 111 Times. Put $f = 427$. $c = 172$. $d = 163$. '$n = 2$ as above, only change F, put F 437.3, that is suppose the Body sunk 'in Water 4 Inches lower; in this case $\alpha = 208$, therefore $a - \alpha = 0.64$ 'which multiplied into $\varphi\, n = 1.28$ cubick Inches, which $\times 253$ gives 324 'Grains; and so much the Body's Top xm being sunk 4 Inches under Water, 'the Body becomes heavier, than while xm was at the Surface of the Water. 'Therefore this 1.28 divided by the aforesaid Depth 4 gives 0.32 the Area 'of the Top-Pipe, such as would balance or buoy up the Body at any Depth. 'Strictly speaking, the Pipe should be gradually bigger upward in order to 'sustain the Instrument at any Depth, but as to Sense 'tis cylindrical, and its 'Circumference = 2.005. But for that the least Alteration of the Air would 'make the Body's Top xm in that case pass thro' the 4 Inches (which 4 Inches 'I suppose all the Variety of Depth that the Instrument has room given it in 'the Bucket to ascend or descend) therefore the Pipe is made a small matter 'bigger, (*viz.*) its Circumference is 2.14; whereby the Pipe, according as the 'Body sinks more, gives more resistance to the descending Body. The 'Pipe's Area is 0.3643: Therefore the Capacity of the Pipe in 4 Inches Alti'tude is = 1.457. But as abovesaid, to give justly no resistance, its Capa-

'city

city should be 1.28. Therefore this 1.28 taken from 1.457, leaves .177 the actual Resistance in 4 Inches Depth, *viz.* ($0.177 \times 253 =$) 44 Grains. But this Resistance will not be the same in all Weathers, in order therefore to calculate what it will be when the ☿ of the common Baroscope is very low: For example, but 28 Inches high $= 392$ of Water, f must be supposed $= 392$, therefore $F = f + b + 1 = 398.3$, and the rest as before, *viz.* $d = 163$, $fc = 67424$. $Fd = 649229$. Thence by the aforesaid Equation $\left.\begin{array}{l} a = 2.59 \\ \alpha = 2.84 \end{array}\right\}$ Therefore $\alpha - a = 0.25$, which $\times\, n$ gives 0.50 cubick Inches, which $\times 253 = 126$ Grains. So that this Baroscope when the ☿ is lowest, is more exact than the common 126 times, supposing the Body immersed afresh when the ☿ is so low. Next while the ☿ is so very low, suppose the Top of the Body depressed 4 Inches under Water; therefore $\phi = F + 4 = 402.3$, the rest are as before, *viz.* $fc = 67424$, then a will be 1.9: but before, while the Top of the Body was at the Surface, a was 2.59. Therefore the Difference 69 × Tube's Area 2, gives 1.38 Cube Inches, which × 253 gives 349 Grains; and so much the Baroscope is heavier when the Top xm is 4 Inches under Water, or which comes to the same, supposing the ☿ at 28, and xm at the Surface: This Baroscope by the ☿'s ascending $\frac{4}{14}$ Inch will become heavier 349 Grains. The Pipe's Capacity in 4 Inches Altitude was 1.457, from which take the abovesaid 1.38, the Residue $= 077$, which × 253 gives 19 Grains in 4 Inches: So that the Pipe will sustain the Baroscope, and also 44 Grains when the ☿ is $30\frac{1}{2}$ high, and but 19 Grains when the ☿ is 28 high. The fewer Grains Difference there are in its sinking thro' 4 Inches, the more nice the Baroscope will be.

‘ There where the Thread cuts the Surface of the Water, is formed a Bubble, therefore this Bubble, while the Instrument sinks in Water 4 Inches, which is all the room that I give it, the Bubble moves on the 2 Diagonal Threads 20 Inches: It follows therefore, that 120 Grains Difference would make the Bubble walk over 120 Inches, if the Threads were so long; but, as it has been above calculated, about 120 Grains Difference of Weight of the Instrument is produc'd by so much of the Alteration of the Air, as would make the ☿ of the common Baroscope $\frac{1}{10}$ Inch; therefore when the Mercury ascends $\frac{1}{10}$ Inch, the Bubble of this new Baroscope ascends 120 Inches; therefore this new Baroscope is more exact than the common Baroscope by about 1200 times.’

Observations made with this new Baroscope.

1. While the ☿ of the common Baroscope is often known to be stationary 24 Hours together, the Bubble of the new Baroscope is rarely found to stand still 1 Minute.

2. Suppose the Air's Gravity increasing, and accordingly the Bubble ascending, during the time that it ascends 20 Inches, it will have many short Descents, of the Quantity of $\frac{1}{2}$ Inch, 1, 2, 3, or more Inches, each of which being over, it will ascend again. These Retrocessions are frequent, and of all Varieties in Quantity and Duration, so that there is no judging of the general

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Course of the Bubble by bare Inspection, tho' you see it moving, but by waiting a little time.

3. A small Blast of Wind will make the Bubble descend; a Blast that can't be heard in a Chamber of the Town, will sensibly force the Bubble downward. The Blasts of Wind sensible abroad cause many of the abovesaid Retrocessions, or Accelerations in the general Course; as I found by carrying my Baroscope to a Place where the Wind was perceptible.

4. CLOUDS make the Bubble descend. A small Cloud approaching to the Zenith works more than a great Cloud near the Horizon. In cloudy Weather the Bubble descending, a Break of the Clouds (or clear Place) approaching to the Zenith, has made the Bubble to ascend; and after that Break had pass'd beyond the Zenith a considerable Space, the Bubble again descended.

5. ALL Clouds (except one) hitherto by me observ'd, have made the Bubble to descend. But the other day the Wind being North, and the Course of the Bubble descending, I saw to the Windward a large thick Cloud near the Horizon, and the Bubble still descended; but as this Cloud drew near the Zenith, it turn'd the way of the Bubble, making it to ascend, and the Bubble continued ascending till the Cloud was all pass'd, after which it resum'd its former Descent. It was a Cloud that yielded a cold Shower of small Hail.

6. [27.——*The horizontal Motion of the Air, being so quick as it is, may in all probability cause some Part of the perpendicular Pressure thereof,* &c.] The horizontal Motion of a Fluid can never take off the perpendicular Pressure, as it may be demonstrated mathematically; for tho' Mr. *Haukshee* made an Experiment to try how the Mercury in the Barometer is affected by high Winds, (see his Book of Physico-Mechanical Experiments) and by the falling of the Mercury, concluded (perhaps led by the Conjecture of such a great Man as Dr. *Halley*) that the horizontal Motion of the Air took off from the perpendicular Pressure: yet we shall shew, in strictly examining the Experiment, that it proves no such thing; tho' it leads us to the Cause of the Mercury dancing in the Barometrical Tube in stormy Weather.

Plate 23. *Fig.* 6.

A is a Copper Fountain containing about six Quarts, into which Air is condens'd by a Syringe, till it contains seven or eight times as much Air as usual, kept in by the Cock B. Then upon the Board K L, supported by the Stands K L and H I, are set up two Barometers, whose Cisterns are contain'd in the Boxes D E, G F, communicating one with another by a Brass Pipe D G. Another Brass Pipe C D coming from the Fountain is screw'd into the Box D E, and over against it a larger Pipe, as E M. Things being thus disposed, upon turning the Cock B the Air rushes out of the Fountain, or Copper Sphere, passing with great Violence over the stagnant Mercury in the Cistern at D E, and so out at the larger Pipe E M. Upon this not only the Mercury in the Tube belonging to D E falls from *e* to *ε*, but also the Mercury

Mercury in the other Barometer falls as much, *viz.* from *f* to *φ*. Now upon ſtrict Examination there is not an horizontal Motion of the Air made over the ſtagnant Mercury, but an Exhauſtion of ſome of it; for if you look at *Fig.* 6. which repreſents the End of the Pipe C D, and the Beginning of the large Pipe E M, expreſs'd by the ſame but ſmall Letters, you will find that the End *d* (repreſenting D) is continued over the ſtagnant Mercury, and, with its End, made conic for that purpoſe, enters a little way into the larger Pipe *e m*, (the ſame as E M) ſo that it does not really blow over the Mercury in the open Air, but by blowing away the Air in E M, an Exhauſtion is made of Part of the Air preſſing over the two Ciſterns D E and G F, whereby the Mercury at *e* and *f* deſcends; but riſes again upon ſhutting the Cock, and ſo every time, juſt as it happens when a Squall of Wind blows, and upon the abating of the Wind the Mercury returns, dancing with a pretty quick Riſe and Fall, till the Storm being quite over, the Mercury riſes very faſt, and with a continu'd Motion. This will be farther illuſtrated, by conſidering a ſtormy Wind blowing over the Surface of the Earth, as repreſented in the next Scheme. Annotat. Lect. X.

Plate 23. *Fig.* 7. Let D L M repreſent the Circumference of the Earth, and C N O P D L M the Atmoſphere, L any particular Place, as, for example, *London*. Suppoſe the Stream of Air or the Wind W to come from the right Hand in the Direction W E: this will carry off ſome of the Top of the Atmoſphere, ſuppoſe the Part A G C B, puſh it up to E, and drive it towards F, ſo that there will be as it were an Hollow at G, and the Column of Air B L, which preſs'd upon *London*, be ſhorten'd, and containing leſs Air than it did, preſs leſs upon the Mercury in the Barometer, ſo that it will fall in the Tube; but as the Wind comes by Squalls, or Puſhes, when the Squall abates, the Air will come back from F, and the Places round where it has been heap'd up, and filling up the Cavity A G C B again, become heavier, and preſs up the Mercury in the Barometer. Now as the Wind blows in the Direction W E, a Tangent of the Earth, as we have obſerv'd, the Inhabitants of *London* will not feel the Wind, being below it, but have reaſon to expect it from the Indications given by the Barometer, and perhaps perceive it in the Motion of the higheſt Clouds before it is ſenſible below. During the whole Storm afterwards the Mercury will dance, till perhaps half an Hour before its End, it will no longer dance, but riſe very faſt. For ſuppoſe then it blows in the Direction *w e*, tho' it be felt ſtill by the Inhabitants of L, the Height of the Column L B will be then ſettled, as there is no ſucceeding Wind to blow in the Direction W E, to diſturb the Atmoſphere at B; and there being no alternate Increaſe and Decreaſe of Preſſure, there will be no dancing of the Mercury in the Barometer, but an uniform and ſteady Increaſe of its Riſe, by the coming in of the Air that had been diſplac'd, and hinder'd from coming in fully, by each returning Squall. Now whilſt all the Mercury is quiet at *London*, (that is, riſes quietly) in another Place to which the Storm is going; ſuppoſe at *Dublin*, repreſented by D, (if the Storm goes from Eaſt to Weſt) the Column of Air over that Place will be alternately lengthen'd and ſhorten'd, and the Mercury dance before the Storm be felt, whilſt it blows ſtill pretty ſtrongly at *London*. *The Atmoſphere* Plate 23. Fig. 7.

being

Annotat. Lect. X. *being here mark'd with the same Letters,* (small ones) *the same Explication will do here.*

7. [27.——*As we see Water runs the faster for having great Declivity.*] This has been sufficiently explain'd in the last Note. See the Figure*, where F A G and C G shews the Declivity, which is to be suppos'd from all Parts round about, when the Storm is wholly ceas'd.

* Plate 23. Fig. 7.

8. [——*The Cause of Mr.* Patrick's *6th, 7th and 8th Articles are explain'd in the Notes.*]

In relation to the sixth Article, *if it rains soon after the falling of the Mercury,* it is a sign that only those Clouds are fall'n into Rain that were very near the Ground; and as this may be owing to a sudden Blast of Wind, or a Flash of Lightning, (whose sulphureous Steams absorb the Air) the upper Clouds, which are specifically lighter, descend gradually, and only come down from an higher to a lower Station, by so small a Change in the Density of the Air; for if their Motion downwards towards their *Æquilibrium,* in an Air of the same specifick Gravity with themselves, (tho' specifically lighter than those Clouds that fell into Rain) be but slow, they will meet no Shock, and consequently they will produce no Rain. Add to this, that after Lightning the Air rushing in from all Parts to fill the Vacuity of the absorb'd Air, will render the Air at that Place heavier than before, and cause all such Clouds as have not been compress'd into Rain by their quick Fall, (which occasions a great Resistance of the lower Air) to rise again, and make fair Weather.

The seventh Article, that says, *That when the Mercury rises much and high in foul Weather, and continues to do so for some time before the foul Weather is over, we may expect a Continuance of fair Weather.* Here we are to consider, that when there has been a great Change made in the Density of the Air, not only the lower Clouds have had a great way to fall to come to their Place of *Æquilibrium,* but also the upper Clouds; and therefore they have mov'd downwards with an accelerated Motion, so as to meet such a Shock from the lower Air, as to drive their Particles of Vapour within the Power of each other's Attraction, so as to form Drops of Rain: and when once a Cloud is chang'd into Rain, tho' the Drops be yet but small, let the Air increase its Density ever so much, yet it will come to the ground, because no Air will have a specifick Gravity able to support it, tho' it may retard it a little. Therefore, since all those Clouds that are become Rain, must fall; when they are all come down, there will be no more left to produce Rain, till the Sky be supply'd with a new Stock of Vapour from the Earth.

Mr. *Patrick* says in his eighth Article, *That in fair Weather, when the Mercury falls much and low, and thus continues for two or three Days before the Rain comes, then we must expect a great deal of Wet, and probably high Winds.* It is to be observ'd, that he does not say when the Mercury falls *quick* and low, but *much* and low; for then that would be the Case of the seventh Article. But we may observe, that when in this Case it falls a great

I while,

while, it falls but a little at a time, but as it continues to fall it may be very low before there is any Rain. Now when the whole Weight of the Air, and consequently its specifick Gravity in each Region, gradually diminishes, each Cloud however it differs in Height from another, has but a little way to fall to come to its own *Æquilibrium*, so that it moves down like a Feather, too gently to meet such a Shock from the inferior Air as will drive its Drops together so as to produce Rain. Therefore all that will happen, is, that the heaviest Clouds will come gently to their *Æquilibrium* very near the Ground, and those which are lighter and higher (for Clouds vary in Depth according as they are made of finer or grosser Vapour, first rais'd from their Cohesion in Water by a greater or a less Heat) come to their new *Æquilibrium* a little lower than their first Place; and at every small Descent of the Mercury all of them descend a little lower without any Shock, till the Sky is overcast, all the Clouds being very low. Now upon the next Fall of Mercury, if it be more considerable, as it will be by a Blast of Wind not check'd; as, for Example, a South, or a South-westerly Wind, the Density of the Air will be so alter'd, that all those Clouds will fall quick enough to meet with a Shock that will so far condense them into Rain, that they cannot rise again before they are fallen to be exhal'd again. Now, as there are many Clouds brought near the Earth, and of such different Densities as to fall with different Velocities, (tho' the slowest fall fast enough to be compress'd into Rain) it will take up some time before they are quite down, and that is the long Run of foul Weather.

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9. [24.——*Between the Tropicks the Rain falls at certain Seasons in very great Quantities, and yet the Barometer shews there very little or no Alteration.*] About the Year 1717 I publish'd this Paper against Monf. *Leibnitz*'s Opinion of the Causes of the Variation of the Barometer, wherein what I said was deduc'd from Hydrostatical Laws, and therefore amounts to a mathematical Demonstration: so that it is needless to say any thing in answer to what is, or may be alledged against it. But M. *Ge. Henricus Rastius* having in the Year 1719 publish'd an Answer to my Paper, has in an Epistle treated me so civilly, that I cannot (now my Subject calls me to it) refuse an Answer to his Objections.

1st then, I say that Monf. *Leibnitz*, and those of his Opinion on this Subject, have mistaken the Effect for the Cause; the Fall of Rain not being the occasion of, but being occasion'd by the Diminution of the Air's Gravity and Density consequent upon it.

To follow M. *Rastius* closely, we will quote such Things as may not directly be answer'd from what I said in my Dissertation. N° 3. He says, "*Leibnitz*, according to the great Capacity of his Mind, contriv'd yet another way to expose more evidently to our Senses the Truth of this Proposition. He would have me take a Balance, from one of whose Brachiums a pretty long Tube must hang, fill'd with a Fluid, as Water, in which a hollow Body must swim, but made of a Substance specifically heavier than Water, and in such manner, that when the Water comes into the Cavity

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Annotat. Lect. X. "of the Body, it shall descend towards the Bottom of the Tube: In the "Scale hanging at the other Brachium he would have an exact Counterpoise "for the Tube, Water and Body. Then he order'd, that the Water might "be made to enter into the Cavity of the Body, which for that purpose must "have a small Hole, so stopp'd at the Beginning of the Experiment, that "the Water in Time should overcome the Resistance of the Stopple, and run "gradually into the Cavity of the Body. And that then this heavy Body, "that had been before sustain'd by the Water, coming to fall, the *Æquilibrium* would be lost between the Tube containing the Water with the Body "falling in it, and its Counterpoise would certainly prevail, because the "Water in the Tube would then have lost something of its Weight. But "this great Man considering afterwards that such a Body could not be made "hollow without great Difficulty, and a Danger of disturbing the *Æquilibrium*, if the Method propos'd to *Ramazzini* was follow'd, in his Epistle "to the famous *Bignon*, substituted, *&c.*"

Now this Experiment which he first propos'd is not very difficult, and may be made in the following manner, and with the following Success.

EXPERIMENT *Plate* 23. *Fig.* 8.

Plate 23. Fig. 8. LET B C D be a Glass Tube, or a long Glass of two or three Inches Diameter, hanging at B from one of the Ends of a Balance, and let it be fill'd with Water to S S; then let an hollow Body of Lead *a b* like an Egg, with a little open Hole at *a* at top, and an Hole at bottom at *b* stopp'd up with Sugar, be set a floating in the Water, whose Surface it will raise up to *s s*: then to all this make an exact Counterpoise in the opposite Scale of the Balance. You will observe by degrees, as the Sugar at *b* melts, the Water will run into the hollow of this leaden Egg, whilst the Air runs out at *a*, so as to fill it, and it will descend in the Tube, as at *c d*, the Surface of the Water also coming down again to S S. You will see the Counterpoise preponderate, and the Tube with its Contents rise: not because the Bottom C D is less press'd on account of the Body falling and losing all its Weight, which before made a Part of the whole Fluid; but because, by the Water running into the Egg it falls from *s s* to S S, and the Pillar of Water S C D *s* has lost of its Height according to which it press'd, and being come down to S S, weighs only as S C D S, which has less Height *. Whilst the Egg is at *a b*, it adds to the Weight of the whole Fluid as much as if an equal Bulk of Water was pour'd in, and that whether the Egg be specifically heavier or specifically lighter than the Water, or of the same specifick Gravity. As the Egg descends it presses upon the Column of Water *c e f d*, and therefore acts more strongly on the Bottom C D, in proportion as it is retarded in its Fall; for if the Tube was long enough for the Egg to be retarded by the Resistance of the Water till it came to an uniform Motion, it would make the Column of Water *c e f d* press enough to recompense the want of Water in the Space *s* S S *s*, and the *Æquilibrium* would be restor'd.

* L. 9.

IN N° 4. *Rastius* says——"Now let us see and examine in a few Words, "why *Desaguliers* and *Leibnitz* could not agree in this Affair. We suppose the "whole

" whole Doctrine to turn upon this, *viz.* the Principle and the Experiment Annotat.
" of *Leibnitz* are the Subject of the Controversy. *Desaguliers* by his Objec- Lect. IX.
" tions does not so much as attack the Principle or this Proposition, *viz.*
" *that Bodies in falling do not gravitate*; that is, directly so as to deny
" any one of the Things suppos'd in the Demonstration, or to shew a Paralo-
" gism committed in it; but yet by what he alledges endeavours to infer
" from some hydrostatical Foundations what should overthrow this first.
" He says, let A B be the Bottom of a Vessel, *&c.*"

Now I don't say it in the very Words, yet what I prove comes to what I say now, *viz.* that Bodies falling in Fluids do gravitate in their Fall, and that with all the Weight whereby their specifick Gravity exceeds that of the Fluid; and that the Momentum which they lose, by the Resistance of the Fluid in which they fall, is communicated to the Fluid so as to make the Column under them gravitate more strongly upon the Bottom on which it stands: and if the Body in its Fall is come to a uniform Motion, the Bottom will be as much press'd as if the Body having fallen thro' the whole Fluid was already there, at rest upon the said Bottom.

Then in N° 5th, *Rastius* makes a difficulty about a Column of a Fluid that is heterogeneous; as if I had not taken notice that that is the case in the Atmosphere. But the Demonstration of the hydrostatical Paradox holds good there too, the Atmosphere being as it were made up of different *Strata*, whose specifick Gravities diminish as we go upwards, except upon some extraordinary Occasions, such as we have taken notice of in N° 7, Page 341.

Nay, if at any time the *Strata* are not plac'd according to their specifick Gravity, they will soon obtain that Position: and Instances may be given when the Pressure shall remain the same, tho' the Scale of Atmospherical Density, or the Sum of all the Densities be alter'd.

Plate 23. *Fig.* 9.

Let us suppose a Column of the Atmosphere confin'd, so that it may not Plate 23. communicate with any other Columns laterally: As it would happen if Fig. 9. A B C D was a Tower enclosing the said Column reaching up to the Top of the Atmosphere, and open at top. Within that Column suppose another, as G E F H, and the whole large Column diminishing in Density from B C to A D. Now if we suppose a large Body, as K, to come into the middle of the above-mention'd large Column, and that Body to be specifically lighter than that Part of the Atmosphere whose room it takes up in the Space *n i l o m k*, as it might happen when a light Cloud is rising up before it is come to its Place of *Æquilibrium*: I say then that the Bottom E F comes to be less press'd than it was, (tho' the Height A D remains the same) because there is less Matter in the Column G E F H than there was: but this only happens if the Cloud fills up the Space of the Tower reaching from *n* to *o*; for if the Cloud does not reach the Sides of the Tower, and leaves a Passage, as *i k* or *l m*, tho' it be larger than the Column G E F H, whose upper Part it divides from the lower; the Pressure will be propagated from G H to E F thro' *i k* and *l m*, tho' the Scale of Density in G E F H be alter'd, and E F will

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be preſs'd as before K was intercepting the middle of it: and that as long as K ſtays where it is, whether it be ſpecifically heavier, or ſpecifically lighter than the Air whoſe Place it takes up.

Plate 19. Fig. 22.

THEN *Raſtius* ſays in N° 6, that by ſpeaking of the Deſcent of the Clouds A, B, (*Plate* 19. *Fig.* 22.) to C D, I muſt ſuppoſe new Matter to be added to them to cauſe their Deſcent, and draws Conſequences againſt me from that Suppoſition. When I mention'd the Clouds firſt at A, B, then at C, D, as I only made a Suppoſition, I did not take notice of what Cauſes would make them riſe and fall, but conſider'd them only as Bulks of ſuch a Bigneſs, which being either in one Part or another of the Atmoſphere, did not by their Removal from one Place to another alter its Height, and therefore did not alter its Preſſure. It is a wrong Notion to think that the Atmoſphere, keeping the ſame Height, muſt always vary in Preſſure every time its Scale of Denſity is alter'd. The Fallacy of it ariſes from want of underſtanding the hydroſtatical Paradox, or rightly applying it. The Preſſure upon the Bottom of any Veſſel, as A B, *Plate* 19. *Fig.* 21. is always the ſame, when the Height is the ſame, tho' the Quantity of Matter be ever ſo different: ſo that the Column C A B D may be diminiſh'd in any Part, or increas'd, except its Baſe and Height, and the Preſſure on the Baſe remain the ſame. Its Quantity of Matter may be 1000 times greater, or a 1000 times leſs *. I know that it will be anſwer'd, that this is only for homogeneous Fluids; but the caſe is not the ſame in heterogeneous Fluids, as the Air. But when a Fluid gradually decreaſes in Denſity, as it happens in pure permanent Air, the Caſe is the ſame; for unleſs the Clouds, Vapours and Exhalations were to incorporate with the Atmoſphere, they are not to be taken into the Scale of Denſity. Whilſt the Air can preſs down between the Clouds, we may look upon any Part of the Surface of the Earth as preſs'd by a Pillar of Air uniformly decreaſing in Denſity from the Ground to the Top of the Atmoſphere, which (tho' it be undetermin'd by reaſon of the inſenſibly decreaſing Denſity of the Air) may be conſider'd as 60 Miles high; weighing as much as a Column of Air equally denſe with what we commonly breathe, of between five and ſix Miles in Height. Indeed if there was a Cap of Clouds continuous, and covering a large Tract of Ground, ſuch as we ſuppos'd the Cloud K, *Fig.* 9. there might be ſome ſmall Alteration in the Scale of Denſity. The Preſence or Abſence of the Clouds does no way diſturb the hydroſtatical Paradox in relation to the Atmoſphere, whilſt they continue in the ſame Place, and if it was poſſible for them to remain in their Places, and be of different ſpecifick Gravities, they would only exclude ſo much Air as was equal to their Bulk; for any Quantity of Air, any how inclin'd, if high enough, and coming freely to the Baſe whoſe Preſſure we conſider, would give the ſame Preſſure. Thus in cloudy Weather, it is a Miſtake to ſay the Air is loaded with Vapours; for the Vapours or Clouds form'd from them only exclude ſo much Air as would fill up the room they take up: for if they were incorporated with the Air, and the watery Particles mix'd in its Interſtices, the whole Air would preſs more, and the Mercury by its Riſe would ſhew it in the Barometer, contrary to Obſervation; the Mercury riſing moſt when the Air is cleareſt.

* L. 7.

Plate

Plate 23. *Fig.* 10. Let C D be Part of the Earth's Surface, and A C D B an atmospherical Column, being most dense at Bottom, and gradually rarer from C D to A B: it is not necessary that there be a certain Quantity of Matter pressing upon C D, to give always a certain Degree of Pressure, provided the Height remain, and Base be free; for the crooked Column C N M I K L O D, containing much less Matter, but the same Height, and the same Decrease of Density as A C D B, will press as much upon C D, tho' pressing in an oblique Direction, by reason of the Interposition of the Bodies N M P L Q O, which we may consider as having no share in that Pressure. And now in complaisance to those who are fond of the Consideration of the Scale of Density, or all the Matter in an atmospherical Column, consider'd as pressing on any Base: I say, that when once the Clouds are at rest, this last Consideration will give the same Pressure as the hydrostatical Paradox. Let C D, *Plate* 23. *Fig.* 10. be Part of the Surface of the Earth press'd by the Atmosphere: we consider the Pressure as proportional to a Column of the Atmosphere, as A C D B without Clouds. Now if we take an equal Part of the Surface of the Earth, as E F, and consider it as press'd by the Column B E F H, made up of Air and Clouds, it will appear that that Column will weigh neither more nor less than A D. Because since the Clouds will not rest, but either rise or fall till they come to a Place or Stratum, where the Air is of the same specifick Gravity with themselves, it will be the same thing as to Pressure, whether the Column G F be all of pure Air, or has in it Clouds weighing just as much at that Air, whose room they take up, all the while supposing the Columns of equal Heights.

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Plate 23. Fig. 10.

Now since I have shewn, that when I mention'd the falling of Clouds, I did not mean that they became heavier by an Addition of new Matter; it may be expected that I should give the Reason of a Cloud's Descent, which I take to be this. When some of the superior Air is carried off by Winds that are uncheck'd, the Air at the same Height as the Cloud being eas'd of some of the Weight that compress'd it expands itself, and becomes specifically lighter than it was; whereby the Cloud that does not expand, but keeps the same Bulk and specifick Gravity is no longer sustain'd, but falls by a Force proportional to the Quantity of Matter whereby it exceeds the expanded ambient Air in Density, till it comes to settle in an Air of the same specifick Gravity with itself, where it finds its Place of *Æquilibrium*. So that it is the Air, by becoming lighter, that makes the Cloud fall, and not the Cloud, by falling, which makes the Air lighter, as Mr. *Leibnitz* would have it.

HERE in N° 7. *Rastius* says, that all that he has quoted from me hitherto might have been pass'd by, as having no great Connection with what follows; but that he only took notice of those Objections, because he would follow me close. I have return'd him the Compliment by being so particular hitherto.

BUT now in N° 8. *Rastius* accuses me of having attributed an Opinion to *Leibnitz*, which neither he nor his Followers hold; namely, "That I say "he affirms that a Body which being detain'd in a Fluid makes up Part of "its Weight, loses all that Weight, when it comes to fall. But that when "*Leibnitz* speaks of the Body not gravitating as it falls, he does not mean

"that

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" that Part of its Gravity, whereby it is *in æquilibrio* with the Fluid; that " this is ascribing to such a great Man an Error, which Beginners in Hydro- " staticks could not be guilty of, *&c.*" Now if this was not Mr. *Leibnitz*'s Meaning, how is this a new Principle? How is the Air become lighter by the falling of Rain, unless it has lost the Weight it had when it sustain'd it. To shew that Mr. *Fontenelle*, from whom I had Mr. *Leibnitz*'s Opinion, thought so as well as I, I beg leave to quote his own Words.——*Mais M.* Leibnitz *dans une Lettre qu'il a écrit a M. l'Abbe Bignon, en donne une Raison plus ingenieuse & plus neuve. Il pretend qu'un Corps étranger qui est dans un Liquide, pêse avec ce Liquide & fait partie de son Poids total, tant qu'il est soutenu; mais que s'il cesse de l'être, & tombe par consequent, son poids ne fait plus partie du Poids du Liquide, qui par la vient a peser moins.* That is—— " But Mr. *Leibnitz*, in a Letter which he has written to Abbé *Bignon*, gives " a more ingenious Reason for it. He pretends, that a strange Body which " is in a Liquid weighs with that Liquid, and makes Part of its total Weight, " as long as it is sustain'd; but if it ceases to be so, and consequently falls, " its Weight no longer makes a Part of the Weight of the Liquid, which " thereby comes to weigh less."

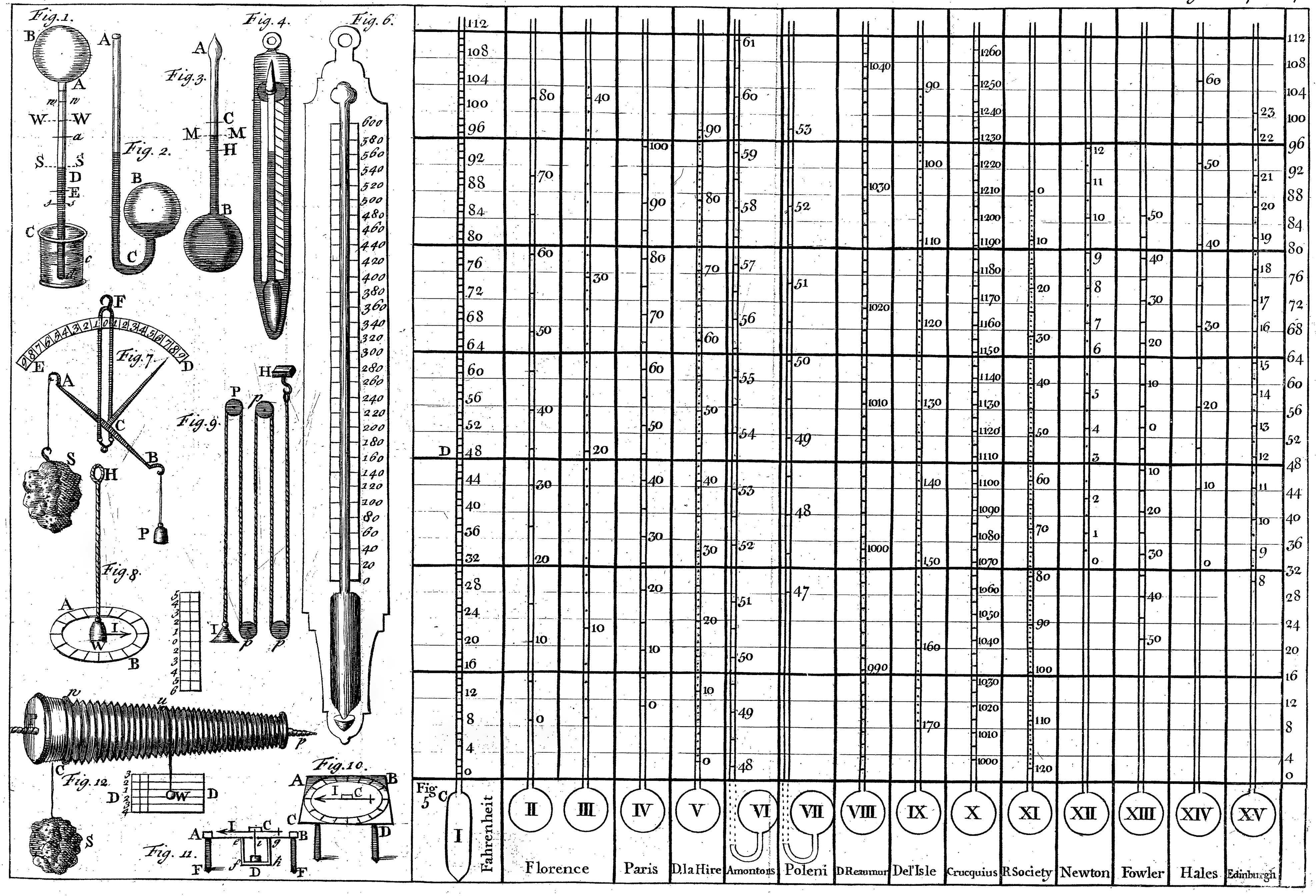
It is not enough to take away from the Air that Part of Gravity whereby the Body over-weighs an equal Bulk of Air, if it still retains that Part wherewith the Body weigh'd with it; for then it won't weigh less than before the Body began to fall.

Now it lies upon me to prove whether there be any Paralogism in the Consequence that Mr. *Leibnitz* draws from the Experiment that Mr. *Ramazini* made by his Direction. Let us examine once more into it, and we shall see that it proves no such thing as it intended to prove.

Plate 19. Fig. 24.

Let us suppose the Weight W, *Plate* 19. *Fig.* 24. to be of Lead, weighing 11 Ounces, and tied by a Thread to B, the End of the Arm of a Balance; but hanging under Water. Now when the Thread is cut just under B, the Counterpoise in the opposite Scale overcomes, and the End B with the Tube, Water and falling Weight W rises as long as the Weight W is falling. From which Mr. *Leibnitz* concludes, that the Tube of Water weighs less, while the Lead is falling in it, than when it was suspended in it. But I say, that no such thing is done, as it will appear when we examine what is done in this Experiment. As Lead is 11 times heavier than Water, by hanging it in Water we only put one Ounce of its whole Weight in Water, (the same as had been done if we had pour'd an Inch of Water into the Tube, which would have rais'd the Water from F B to E H) whereupon it is requir'd to add one Ounce to the Counterpoise of the Tube and Water in the opposite Scale. Then the 10 Ounces that are left in the immers'd Lead pull down the Thread. The Thread being tied to the Arm B, that Arm receives a Weight of 10 Ounces, which must be counter-pois'd by 10 Ounces more in the opposite Scale. Now when you cut the Thread you take off 10 Ounces from the Arm B, which thereby rises up by the Force of 10 Ounces in the opposite Scale, so that B is made lighter; and brings up along with it the Tube, and Lead, and Water, which is really heavier: for the 10 Ounces taken

Plate XXII. *Frontisp. p. 364.*



taken off from B are given to W, which falls thereby; but as the Water yields to the falling Lead, it gives the Water but Part of that Weight at a time; but if the Tube had Length enough to come to an uniform Motion, the Preſſure of the Water upon the Bottom D I would be as great before the Lead came to the Bottom, as when it ſhould be come to it. Nay, as ſoon as the Lead begins to fall, the Water becomes heavier, provided that before the Thread be cut the Lead that hangs in the Water be ſuſpended from no Part of the Brachium of the Balance B. The Experiment then muſt be made as repreſented by *Fig.* 23. which I need not repeat, having already deſcrib'd it, and the Tube will ſink the very Moment that the Thread is cut. Annotat. Lect. X.

Raſtius, in N° 13, is pleas'd to be merry about this way of making the Experiment——" Without doubt, ſays he, *Deſaguliers* is far from the Opi-" nion, that the Vapours affording Matter for Rain are ſupply'd by ſome " *Genii* or *Spirits*, (like the heavy Body held in Water by the Hand) and " not held up aloft by the *Æquilibrium* of the circumfluent Air."——The Joke is ſo good, that here I leave Mr. *Raſtius* to enjoy it.

10. [33.——Dr. *George Martine*, &c.] The late Dr. *G. Martine*, in his Book of Eſſays, printed at *London* for *A. Millar*, 1740. has four upon the Subject of Thermometers, wherein he has treated that Matter excellently well; and as the whole is worth conſidering, and I have not room here to inſert it, I muſt refer my Reader to the Book. I have only copied from him in one of my Plates the ſeveral Thermometers which he compares, and here I'll mention the Heads of what he treats of in thoſe Eſſays that relate to our Subject.

" Essay 3. Of the Conſtruction and Graduation of Thermometers.

" Essay 4. Of the Compariſon of different Thermometers.

" Essay 5. Of the Heating and Cooling of Bodies.

" Essay 6. Of the various Degrees of Heat in Bodies, containing eight " Articles, which are as follows, *viz.* 1. The way of computing the diffe-" rent Degrees of Heat. 2. The Heat of the Air. 3. The comparative " Heats of the Sun, Earth, Planets, and Comets. 4. The Degrees of " Heat in Animals. 5. The preternatural Heats of Animals. 6. The " Heats of Waters, Oils and Salts, according to their Fluidity and Con-" ſiſtency. 7. The melting and ſhining Heats of Metals and Minerals. 8. " The boiling Heat of liquid and melted Bodies."

In the Year 1741 I had a curious Spirit-Thermometer ſent to me from *Paris* by Mr. *Micheli du Creſt*, of his Invention, which I think to be one of the beſt Spirit-Thermometers that ever I ſaw. It has four Scales beſides its own, *viz.* according to the old Thermometer of the Royal Obſervatory at *Paris*, according to Mr. *de Reaumur*, according to Mr. *de l'Iſle*, and according to *Farenheit*. He alſo ſent me particular Directions for the making of it, with all the neceſſary Cautions to be obſerv'd; but as I have already declar'd my preferring the mercurial Thermometer, and my Reaſons for it, I ſhall not communicate Mr. *du Creſt*'s Paper here.

11.

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11. [33.——*This is only when Water boils in open Vessels.*] Tho' boiling Water be mark'd as a fix'd Point on the Thermometer, yet it may lead one into an Error, because boiling Water is hotter when the Air is heavy, than when it is light; so that to fix the Degree of Heat of boiling Water on the Thermometer, we must mention the Height of the Barometer at that time. For when the Barometer is very low, suppose at 28 Inches, a less Degree of Heat will make it boil, as it is press'd by a less heavy Atmosphere; and a greater Degree will throw it off in Vapour. But when it is very fair Weather, and the Barometer stands at near 31 Inches, a much greater Degree of Heat is requir'd to make it boil, it being then press'd with near $\frac{1}{10}$ more on account of the Air's increas'd Weight. A greater Degree of Heat than what makes it boil then will not remain in the Water, because it will make it evaporate. If the Water was press'd with a still heavier Atmosphere, it would require more Heat to make it boil, only because it would keep its Parts more strongly together; for it is not true that Water, as Water, is not capable of a greater Degree of Heat than what makes it boil: but Water *as it is circumstanc'd*, as it is press'd by an Atmosphere not weighing above 15 Pounds 11 Ounces upon an Inch, is not capable of retaining a greater Degree of Heat, &c. But if the Surface of the Water has a greater Resistance than that of the Atmosphere by being confin'd in a close Vessel, it is susceptible of much more Heat. Professor *Muschenbroek* told me, that in *Papin*'s Digester he made Water so hot that it melted Lead. And I have often seen it melt the Solder, (made of Lead and Tin) which held together the Parts of the Copper Vessel in which it was heated, when confin'd. We are forc'd to use what is call'd hard Solder, made of Spelter, or of Silver and Brass; to make Brass or Copper Vessels hold the Water confin'd, and much heated, without melting in the Joints.

Oils have a much stronger Cohesion of Parts than Water, especially Linseed Oil, which requires four times the Heat that Water does to make it boil. Water has so little Tenacity, that if it was not for the Pressure of the Atmosphere, a very small Degree of Heat would separate its Parts, and turn it into Vapour; for when it is but a little hotter than new Milk from the Cow, upon taking off the Pressure of the Atmosphere by the Air-Pump, that small Degree of Heat makes it evaporate. Nay, so little Tenacity in Water does any Experiment yet made shew, that I question *whether the Parts of Water touch one another* any more than those of Air, tho' they are generally nearer together than those of Air. But dare not pronounce any thing concerning that Matter for want of sufficient Experiments. The repellent Force of Water, as Water, (for here I take no notice of the Force that actuates its Particles, when turn'd to Steam) is immensely great, tho' it reaches but a little way; for the Attraction of Cohesion begins at a very small Distance. It is the repulsive Force which makes Water incompressible; and it is greater than the repulsive Force of Air at the same Distance. For from a remarkable Experiment already mention'd, of Dr. *Hales*, it appears that the Particles of Air can be brought nearer together than those of Water. I mean the Air condens'd in the

the Bomb that he broke by freezing, which was about 1600 times denſer than common Air, and conſequently twice denſer than Water. Page 245, 246, 247. of this Book. Now let us conſider, ſince we have ſhewn the conſtituent Parts of Air to be bigger than thoſe of Water, whether it is not poſſible for the Parts of Water not to touch one another, ſince they could never be brought to a Denſity above half ſo great as Air has been brought to. Annotat. Lect. X.

12. [38.———*Thoſe Philoſophers who aſſert the being of an elementary Fire* ———*aſſert a little too much.*] In Dr. *Hales*'s Vegetable Staticks, Volume 1. Page 28, *& ſeq.* you'll find Sir *Iſaac Newton*'s Opinion and his about the Nature of Fire in the following Words———" Is not Fire a Body " heated ſo hot as to emit Light copiouſly? For what elſe is a red-" hot *Iron* than Fire? And what elſe is a burning *Coal*, than red-" hot *Wood?* Qu. 10. Is not Flame a Vapour, Fume or Exhalation " heated red-hot; that is, ſo hot as to flame? For Bodies do not flame " without emitting a copious Fume, and this Fume burns in the Flame. " ———Some Bodies heated by Motion or Fermentation, if the Heat " grows intenſe, fume copiouſly; and if the Heat be great enough, the " Fumes will ſhine, and become Flame: Metals in fuſion do not flame for " want of a copious Fume, except Spelter which fumes copiouſly, and " thereby flames: All flaming Bodies, as Oil, Tallow, Wax, Wood, Foſ-" ſil Coals, Pitch, Sulphur, by flaming waſte and vaniſh into burning " Smoak; which Smoak, if the Flame be put out, is very thick and viſible, " and ſometimes ſmells ſtrongly, but in Flame loſes its Smell by burning; " and according to the Nature of the Smoak the Flame is of ſeveral Colours, " as that of Sulphur, blue; that of Copper open'd with Sublimate, green; " that of Tallow, yellow; that of Camphire, white; Smoak paſſing thro' " Flame cannot but grow red-hot, and red-hot Smoak can have no other " Appearance than that of Flame."

But Mr. *Lemery* the younger ſays, " That the Matter of Light produces " Sulphur, being mix'd with Compoſitions of Salt, Earth, and Water, and " that all inflammable Matters are ſuch only in virtue of the Particles of Fire " which they contain. For in the Analyſis, ſuch inflammable Bodies pro-" duce Salt, Earth, Water, and a certain ſubtile Matter, which paſſes thro' " the cloſeſt Veſſels; ſo that what pains ſoever the Artiſt uſes, not to loſe any-" thing, he ſtill finds a conſiderable Diminution of Weight.

" Now theſe Principles of Salt, Earth and Water are inactive Bodies, " and of no uſe, in the Compoſition of inflammable Bodies, but to detain " and arreſt the Particles of Fire, which are the real, and only Matter of " Flame.

" It appears therefore to be the Matter of Flame that the Artiſt loſes in " de-compounding inflammable Bodies, *Mem. de l'Acad. Anno* 1713."

But

Annotat. Lect. X.

But by many of the preceding Experiments, it is evident, that the Matter loft in the Analyfis of thefe Bodies was elaftick Air, a very active Principle in Fire, but not an elemental Fire as he fuppofes.

"Mr. *Geoffrey* compounded Sulphur of acid Salt, Bitumen, a little Earth "and *Oil* of *Tartar*." *Mem. de l'Acad. Anno* 1703. In which *Oil* of *Tartar* there is much Air, by Experiment 74; which Air was doubtlefs by its Elafticity very inftrumental in the Inflammability of this artificial Sulphur.

If Fire was a particular diftinct kind of Body inherent in Sulphur, as M. *Homberg*, Mr. *Lemery*, and fome others imagine, then fuch fulphureous Bodies, when ignited, fhould rarefy and dilate all the circumambient Air; whereas it is found by many of the preceding Experiments, that acid fulphureous Fuel conftantly attracts and condenfes a confiderable Part of the circumambient elaftick Air. An Argument, that there is no Fire endued with peculiar Properties inherent in Sulphur; and alfo that the Heat of Fire confifts principally in the brifk vibrating Action and Re-action, between the elaftick repelling Air, and the ftrongly-attracting acid Sulphur, which Sulphur in its Analyfis is found to contain an inflammable Oil, and acid Salt, a very fix'd Earth, and a little Metal.

Now Sulphur and Air are fuppofed to be acted by that ethereal Medium, "by which (the great Sir *Ifaac Newton* fuppofes) Light is refracted and re-"flected, and by whofe Vibrations Light communicates Heat to Bodies, and "is put into Fits of eafy Reflection and eafy Tranfmiffion: And do not the "Vibrations of this Medium in hot Bodies contribute to the Intenfenefs and "Duration of their Heat? And do not hot Bodies communicate their Heat "to contiguous cold ones, by the Vibrations of this Medium, propagated "from them into cold ones? And is not this Medium exceedingly more rare "and fubtile than the Air, and exceedingly more elaftick and active? And "does it not readily pervade all Bodies? *Opticks qu.* 18. The elaftick Force "of this Medium, in proportion to its Denfity, muft be above 490,000,000,000 "times greater than the elaftick Force of the Air is, in proportion to its Den-"fity, *ibid*, *qu.* 21." A Force fufficient to give an intenfe Degree of Heat, efpecially when its Elafticity is much increafed by the brifk Action and Reaction of Particles of the Fuel and ambient Air.

From this manifeft Attraction, Action, and Re-action, that there is between the acid, fulphureous, and elaftick aëreal Particles, we may not unreafonably conclude; that what we call the Fire-Particles in Lime, and feveral other Bodies, which have undergone the Fire, are the fulphureous and elaftick Particles of the Fire fixed in the Lime; which Particles, while the Lime was hot, were in a very active, attracting, and repelling State; and being, as the Lime cooled, detained in the folid Body of the Lime, at the feveral attracting and repelling Diftances they then happened to be at, they muft neceffarily continue in that fixed State, notwithftanding the æthereal Medium, which is fuppos'd freely to pervade all Bodies, be continually follicіting them to Action: But when the folid Subftance of the Lime is diffolved, by the Affufion of fome Liquid, being thereby emancipated, they are again at liberty to be influenced and agitated by each other's Attraction and Repulfion, upon which

which a violent Ebullition enſues, from the Action and Re-action of theſe Particles; which Ebullition ceaſes not, till one Part of the elaſtick Particles are ſubdued and fixed by the ſtrong Attraction of the Sulphur, and the other Part is got beyond the Sphere of its Attraction, and thereby thrown off into true permanent Air: And that this is a probable Solution of the Matter, there is good reaſon to conclude from the frequent Inſtances we have in many of the foregoing Experiments, that Plenty of elaſtick Air is at the ſame time both generated and abſorbed by the ſame fermenting Mixture; ſome of which were obſerved to generate more Air than they abſorbed, and others *è contra*, abſorbed more than they generated, which was the caſe of Lime.

EXPERIMENT 119.

AND that the ſulphureous and aëreal Particles of the Fire are lodged in many of thoſe Bodies which it acts upon, and thereby conſiderably augments their Weight, is very evident in Minium or red Lead, which is obſerved to increaſe in Weight about $\frac{1}{20}$ Part in undergoing the Action of the Fire; the acquired Redneſs of the Minium, indicating the Addition of Plenty of Sulphur in the Operation: For Sulphur, as it is found to act moſt vigorouſly on Light, ſo it is apt to reflect the ſtrongeſt, *viz.* the red Rays; and that there is good ſtore of Air added to the Minium, I found by diſtilling firſt 1922 Grains of Lead, from whence I obtained only ſeven cubick Inches of Air; but from 1922 Grains, which was a cubick Inch of red Lead, there aroſe in the like Space of Time 34 cubick Inches of Air; a great Part of which Air was doubtleſs abſorbed by the ſulphureous Particles of the Fuel, in the reverberatory Furnace, in which the Minium was made; for by Experiment 106, the more the Fumes of a Fire are confined, the greater Quantity of elaſtick Air they abſorb.

IT was therefore doubtleſs this Quantity of Air in the Minium which burſt the hermetically ſealed Glaſſes of the excellent Mr. *Boyle*, when he heated the Minium contained in them by a burning Glaſs; but the pious and learned Dr. *Nieuwentyt* attributes this Effect wholly to the Expanſion of the Fire-Particles lodged in the Minium, "He ſuppoſing Fire to be a particular Fluid "Matter, which maintains its own Eſſence, and Figure, remaining always "Fire, tho' not always burning. *Religious Philoſopher*, p. 310."

TO the ſame Cauſe alſo, excluſive of the Air, he attributes the vaſt Expanſion of a Mixture of *compound Aqua-fortis* and *Oil* of *Carraways*, whereas by *Exper.* 62. there is a great Quantity of Air in all *Oils.* And by pouring ſome compound *Aqua fortis* on Oil of Cloves, the Mixture expanded into a Space equal to 720 times the Bulk of the Oil, that Part of the Expanſion, which was owing to the watery Part of the *Oil* and *Spirit*, was ſoon contracted; whereas the other Part of the Expanſion, which was owing to the elaſtick Air of the *Oil*, was not at all contracted till the next Day, by which time the ſulphureous Fumes had reſorbed it.

THE learned *Boerhaave* would have it, that Putrefaction is the Effect of inherent Fire. He ſays, "That Vegetables alone are the Subject of Fermen-"tation, but both Vegetables and Animals of Putrefaction; which Opera-

Annotat. Lect. X. " tions he attributes to very different Cauſes: the immediate Cauſe of Fermentation is (he ſays) the Motion of the Air intercepted between the fluid " and viſcous Parts of the fermenting Liquor; but the Cauſe of Putrefaction " is Fire itſelf, collected or included within the putrefying Subject, *Proceſſ.* " 77." But I do not ſee why theſe may not reaſonably enough be looked upon as the Effects of different Degrees of Fermentation; Nutrition being the genuine Effect of that Degree of it, in which the Sum of the attracting Action of the Particles is much ſuperior to the Sum of their repulſive Power: But when their repelling Force far exceeds their attractive, then the component Parts of Vegetables are diſſolved. Which diſſolving Subſtances, when they are diluted with much Liquor, do not acquire a great Heat in the Diſſolution, the Briſkneſs of the inteſtine Motion being checked by the Liquor: But when they are only moiſt, like green and damp Hay, in a large heap, then they acquire a violent Heat, ſo as to ſcorch, burn, and flame, whereby the Union of their conſtituent Parts being more thoroughly diſſolved, they will neither produce a vinous, nor an acid Spirit. Which great Degree of Solution may well be effected by this means, without the Action of a Fire, ſuppoſed to be included within the putrefying Subject. Wherefore, according to the old Axiom, *Entia non ſunt temere neque abſque neceſſitate multiplicanda.*

13. [44.——*Machine for taking Levels.*] In *Phil. Tranſact.* N° 385. you will find the following Account of my Machine for taking Levels.

(1.) THAT the Air-Thermometer is alſo a Barometer, has been obſerv'd long ago; and, becauſe the Liquor in it will riſe and fall, as well by the Change of the Weight of the Air, as by the Air's Rarefaction by Heat and Cold, this Inſtrument has no longer been made uſe of as a Thermometer, and in its ſtead Spirit-of-Wine Thermometers hermetically ſealed have been uſed ever ſince.

BUT becauſe the Errors of the Air-Thermometer, (or its Difference from the Spirit-Thermometer) depend only upon the Change of the Weight of the Atmoſphere from what it was, when the two Thermometers were ſet at the ſame Degree of their reſpective Scales; the late Dr. *Hooke* contriv'd an Inſtrument, that he called a *Marine Barometer*, made of a Combination of the two above-mentioned Thermometers, in ſuch manner that a third Scale being made uſe of to obſerve the Difference of the two Thermometers, thereby the Change of the Air's Gravity, and conſequently Storms, Rains and fair Weather, might be fore-told at Sea, where the Quickſilver Barometer becomes uſeleſs by the ſhaking of the Ship.

DR. *Halley*, ſome Years ago, publiſhed two Tables to ſhew how much the Mercury in the Barometer would ſubſide, when the Inſtrument is carried up to determinate Heights above the Level of the Place where the firſt Obſervation was made; but as he makes only one tenth of an Inch of Fall of Mercury, to correſpond with an Height of 90 Feet (which Height is rather of the leaſt) it is evident that only very high Hills and Mountains can have their Heights determined by this Method. The ſame learned Profeſſor has lately, in the *Philoſophical Tranſactions*, propoſed Mr. *Patrick*'s Pendent Barometer, for taking the Level of diſtant Places, becauſe the *Mercury* in the

Tube

Tube of the said Barometer, does sometimes rise and fall a Foot or a Foot and a half: If therefore the Motion of the *Mercury* in this Barometer, be five times more sensible than in the common one, a tenth of an Inch of Fall of the Mercury, will answer to an Height of 18 Feet; and therefore such an Instrument might be of use in taking the Levels of distant Places. But I know by many Experiments that this won't answer in practice; because as the Tube of such a *Barometer* is of a very small Bore, the Attraction of Cohesion, whereby the *Mercury* is apt to adhere to the Tube, will disturb the Motion of the Mercury caused by the different Pressure of the Atmosphere; so that setting up this *Barometer* several times successively in the same Place, it will often differ a tenth of an Inch, or more; and if it be shaken, as is commonly done to set it right, the *Mercury* will sometimes part, and a Drop of it fall from the rest; so that it is less to be depended upon for this Use, than the common Barometer. Annotat. Lect. X.

Mr. *Stephen Gray* has often made a very sensible *Barometer* in the following manner: Into a Bottle C B (*Fig.* 11.) he fixes a Tube A B, *Plate* 23. *Fig.* 11. of a very small Bore, open at both Ends, and cemented tight to the Neck of the Bottle at C; then having warm'd the Bottle with the Hand to drive some of the Air out of it, he immerges the End A into Water ting'd with Cochineal; so that as the Air cools in the Bottle C B, some of the red Water is forced into the Bottle: then setting the Bottle upright again as in the Figure, the Liquor in the Bottle will stand at B, (above the End of the Tube) and that in the Tube at D; but if it should stand higher or lower than D, it may be brought to that Place by sucking or blowing at A. The Instrument thus prepar'd, if it be first set on the ground, and a springing Ring of fine Wire slipped on the Tube down to D, by way of Index, and then set upon any Table or other Place scarce a yard higher, one may observe that the Liquor is risen sensibly. I have seen it rise a quarter of an Inch, when the Bottle was set but a yard higher than where it stood before; so that the Column of Atmosphere that press'd down the Tube, whilst the Machine was on the ground, being shorten'd only three Feet, was so over-balanced by the Expansion of the Air in the Bottle at B, that the Liquor rose a tenth of an Inch above D. There is indeed a great Uncertainty in this Instrument; for since it is a *Thermometer* as well as a *Barometer*, the Warmth of the Hand that touches it, or even comes near it, will make it rise, if the Air in the Bottle was cold before. Mr. *Gray* therefore contriv'd to put the Bottle C B into the Vessel F E which he filled with Sand; that in raising the Instrument, and moving it up and down, the Air in C B might continue in the same state, and the Machine be only a *Barometer* during the Experiment. This seems to bid fair for an Instrument, whereby the different Levels of Places may be taken; but upon a nice Examination, it will be liable to Error: for in the first place, tho' Sand is not altered in its Heat or Cold suddenly, yet in two or three Hours, as it is carried into a warmer or colder Place, it will become hotter or colder, and the least Degree of Heat or Cold communicated to the Air C B, will alter the Height of the Liquor at D. When the Instrument is made so sensible, as I have mentioned, then if in carrying the Instrument it should Plate 23. Fig. 11.

 accidentally

Annotat. Lect. X. Plate 23. Fig. 12, 13, 14, 15, 16, 17.

accidentally be inclin'd (as in *Fig.* 12.) so that the Liquor in the Bottle should not cover the Bottom of the Tube at B, some Liquor may fall out of the Tube at B, or some Air may get into it; each of which Accidents, will quite spoil the Experiment. But if this Machine be made portable, without any Inconveniency, and be secur'd against the Action of Heat and Cold (or which is the same, if the Alterations by Heat and Cold be exactly allow'd for) it will be of very great use and certainty in taking the Levels of distant Places, provided they be not so far distant from each other, that it requires above six Hours time to carry the Instrument from one Place to another; nay, very distant Places, even at two or three Days Journey from one another, may be taken tolerably well with two Instruments, nicely adjusted to each other, if they be taken notice of by two Observers at the same Hour, in fair Weather, and when there is no Wind. Now, such an Instrument, I hope, I have contrived, whereby the Difference of Level of two Places, which could not be taken in less than four or five Days with the best Telescope Levels, may be taken in as few Hours. To the Ball C (*Fig.* 13.) is join'd a recurve Tube BA, of a very fine Bore, with a small Bubble at top at A, whose upper Part is open. It is evident from the Make of this Instrument, that if it be inclin'd in carrying, no Prejudice will be done to the Liquor, which will always be right both in the Ball and the Tube when the Instrument is set upright: If by Heat, the Air at C be so expanded, as to drive the Liquor to the Top of the Tube, the Cavity A will receive the Liquor, which will come down again and settle at D, or near it, according to the Level of the Place where the Instrument is, as soon as the Air at C returns to the same Tenor in respect to Heat and Cold, to preserve the same Degree of Heat when the different Observations are made. The Machine is fix'd in a Tin Vessel FE, filled with Water up to gH, above the Ball; and a very sensible Thermometer has also its Ball under Water, that one may observe the Liquor at D, in each Experiment, when the Liquor in the Thermometer stands at the same Height as before. The Water is pour'd out when the Instrument is carried, which one may do conveniently by means of the wooden Frame of *Fig.* 4. which is set upright by means of three Screws; such as S, and a Line and Plummet. PP, the back Part of the wooden Frame, is represented by *Fig.* 17. where, from a Piece at top, K, hangs the Plummet P, over the Brass Point at N: M*m* are Brackets to make the upright Board KN continue at right Angles with the horizontal one at N. The 16th *Figure* does likewise represent the wooden Frame and Screws. The 15th *Figure* represents the Machine seen in Front, supposing the Fore-part of the Tin-Vessel transparent; and here the Brass Socket of the recurve Tube, into which the Ball is screw'd, has two Wings at II fix'd to the Bottom, that the Ball may not break the Tube by its endeavour to emerge when the Water is pour'd in as high as gh. After I had contriv'd the Machine, as above-mentioned, I consider'd, that as the Tube is of a very small Bore, if the Liquor should rise into the Ball A in carrying the Instrument from one Place to another, some of it would stick to the Sides of the Ball A, and that upon its Descent, in making the Experiment, so much might be left behind, that the Liquor wou'd not be high enough at

D,

D, to shew the Difference of Level; therefore to prevent that Inconveniency, I have contriv'd a Blank Screw to shut up the Hole at A, (*Fig.* 13, *and* 15.) as soon as one Experiment is made, that in carrying the Engine the Air in A may be in Balance with that in C, so that the Liquor shall not run up and down the Tube whatever Heat and Cold may act upon the Instrument, in going from one Place to another. Now, because one Experiment being made in the Morning, the Water may be so cold that when a second Experiment is made at Noon the Water cannot be brought to the same Degree of Cold that it had in the Morning; therefore in making the first Experiment, warm Water must be mixed with the cold, and when the Water has stood some time, before it comes to be as cold as it is likely to be at the warmest Part of the Day, observe and set down the Degree of the Thermometer at which the Spirit stands, and likewise the Degree of the Water in the Barometer at D; then screw on the Cap at A, pour out the Water and carry the Instrument to the Place whose Level you wou'd know, there pour in your Water; and when the Thermometer is come to the same Degree as before, open the Screw at top and observe the Liquor in the Barometer. My Scale for the Barometer is ten Inches long, and divided into Tenths, so that such an Instrument will serve for any Heights not exceeding ten Feet, each Tenth of an Inch answering to a Foot of Height. *N. B.* I have not made any allowance for the Decrease of Density in the Air, because I don't propose this Machine for measuring Mountains, (tho' with proper Allowance for the decreasing Density of the Air it will do very well) but for Heights to be known, Gardens, Plantations, and the Conduct of Water, where an Experiment that answers to two or three Foot in a Distance of twenty Miles, will make this a very useful Instrument. Annotat. Lect. X.

HERE it will not be improper to add a Contrivance of *Fahrenheit's*, of a Mercurial Thermometer turn'd into Barometer, communicated by him in the same *Philosophical Transactions*, N° 385. Here follows the Translation of his Description:

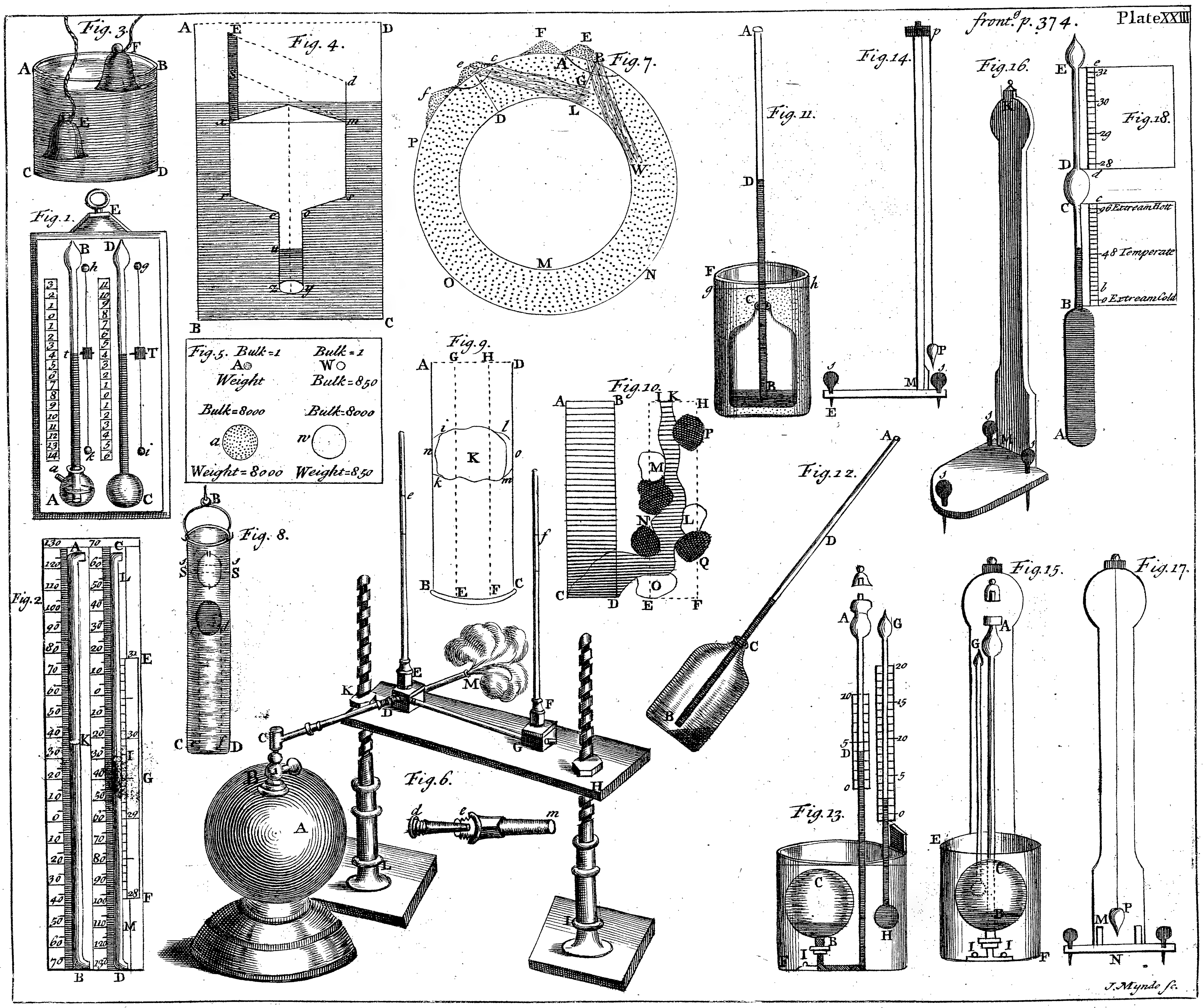
IN the Account I gave of some Experiments concerning the boiling of some Liquors, which I tried, I mention'd that the Degree of boiling Water was confined within the Term then mentioned, namely of 212; afterwards I learned by various Observations and Experiments, that that Term, when the Weight of the Atmosphere remained the same, was fix'd enough; but that the Weight of the Atmosphere varying, that Term might also differently vary. I shou'd now give the Experiments made with that view; but because I want still to learn certain Circumstances, I will defer the giving an account of them to another time, and in the mean time only make mention of a Thermometer, which perhaps may be as fit to find out the Atmosphere's Gravity as the Barometer, if not fitter. The Draught of it is to be seen, *Plate* 23. *Fig.* 18. Plate 23. Fig. 18.

To the Cylinder AB is join'd the Tube BC, to which is added an oblong Globe CD, and to that a little Tube with a very small Hole DE. Let the Cylinder be fill'd with any Liquor that will bear the Heat of boiling Water. In the Tube BC the Degrees of Heat in the Air will be measur'd by the

Annotat. Lect. X.

the annex'd Scale *b c*. Now if that Thermometer be put upon boiling Water, the Liquor of the Thermometer will not only fill the Globule CD, but also rise to the different Terms of the little Tube DE, according to the Degree of Heat which the Water in the time of the Experiment will acquire from the Weight of the Atmosphere. So that, if for example at the time of the Experiment the Height of the Mercury in the Barometer be of 28 *London* Inches, the Liquor in that Thermometer will come to the lowest Place of the Tube DE; but if the Gravity of the Atmosphere be equipollent to an Height of Mercury of 31 Inches, the Liquor raised by the Heat of boiling Water will go up to the top of the Tube DE; but the various Terms of the Heat of boiling Water will not be measur'd by Degrees, but instead of them by the Number of Inches, by which the Height of the Mercury in Barometers is commonly measur'd, namely by Help of the added Scale *d e*.

LECTURE



front.g p. 374.
Plate XXIII
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5. Bulk=1
A
Weight
Bulk=8000
Weight=8000
Bulk=1
W
Bulk=850
Bulk=8000
Weight=850
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
96 Extream Hott
48 Temperate
0 Extream Cold
J. Mynde sc.

LECTURE XI.

HYDROSTATICKS.

Of the Air-Pump, Condensing Engines, and Wind-Gun.

HAVING treated of moſt of the Properties of the Air, and explain'd the Inſtruments relating to the Weather, as Barometers, Thermometers, and Hygrometers; we have nothing farther to do in relation to our Hydroſtaticks and Pneumaticks, but to illuſtrate farther what has been explain'd and demonſtrated, by deſcribing the Air-Pump, and giving 50 of the moſt entertaining Experiments upon that Machine, which will enable the Reader to make 500 more if he pleaſes. Lect. XI.

WE ſhall then ſhew the Manner of condenſing Air, and deſcribe ſeveral Machines for that purpoſe; and conclude with ſome Miſcellaneous Phænomena and Obſervations concerning the Air, taking in what could not properly be conſider'd any where elſe.

A Deſcription of the AIR-PUMP. *Plate* 24. *Fig.* 1.

THE Air-Pump (repreſented in *Plate* 24. *Fig.* 1.) conſiſts of two Braſs Barrels or Cylinders, as repreſented by *a a a a*, twelve Inches in Height, and two their Diameters within. The Suckers, or *Emboli*, are raiſed and depreſſed, by turning the Winch *b b* backward and forward. The Winch is faſten'd to a Spindle, that paſſes thro' a Lantern, whoſe Pins perform the Office of Cogs; for in its Motion, they lay hold on the Teeth of the Racks *c c c c*, and ſo reciprocally as one is depreſs'd, the other is elevated: By which means the Valves, which are made of limber Bladder, and fix'd on the upper Part of each Embolus, as well as at the Bottom of the fore-mention'd Cylinders, perform their Offices mutually of exhauſting and diſcharging the ſame Air, taken from the Recipient or Receiver on the Plate of the Pump. And when the Recipient comes to be pretty well exhauſted of its contain'd Air, the Preſſure of the outward Air on the deſcending Sucker is nearly ſo great, that the Power requir'd Plate 24. Fig. 1.

to

Lect. XI. to raise the other is very little more, than what surmounts the Friction of the moving Parts; which renders this Pump preferable to all others; for, in the working of them, the nearer they approach a *Vacuum*, the greater is their Labour: But this that I am now describing (under the same Circumstances) is quite contrary.

The Bottom of the Barrels are placed in a Brass Dish, represented by *d d*, whose Sides are about two Inches high, and is on purpose to put Water in, to keep the Leather Collars (on which the Brass Cylinders stand) moist, whereby the Air is prevented from insinuating into the Cylinders in those Parts. The Cylinders are screw'd down on the same by the Nuts *e e e e*, which force the Frontispiece *f f* down on them, thro' which the two Pillars *g g g g* pass: The Pillars have an Iron belonging to each of them, and pass from them in the form of a Swan's Neck, describ'd by *g g*, which Irons are fasten'd to the hinder Part of the Frame, for their better Security from shaking.

From between the two Brass Barrels arises a Brass hollow Wire *h h h h*, which hath a communication with each of them, by means of a perforated Piece of Brass, which lies along horizontally from one to the other. The upper End of this hollow Wire is fasten'd to another Piece of perforated Brass *n n*, which screws on underneath the Plate EF, which is ten Inches over, and has a Brass Rim solder'd on it, to prevent the shedding of Water; for which there is occasion in several Experiments. Between the Middle and the Side of this Plate arises a small Pipe *k*, about an Inch and half in Height, thro' which into the fore-mention'd hollow Wire passes all the Air into the Barrels, as it is taken from the exhausting Receiver. Upon the Plate of the Pump is always laid a wet Leather, on which the Recipients are placed: This wet Leather prevents the Air's getting into the Glasses, whose Edges are truly ground, and is of use for that purpose beyond any Cement whatsoever, and not only secures it from the Air's Ingress that way, but by the Use of it we can make several Experiments in the same time they formerly could make one, without any daubing or difficulty. Another Excellency in this Pump is, the Contrivance of the Gage, denoted by *l l l l*, which Gage is a Glass Tube about 34 Inches long, and is so placed that it cannot easily receive Damage, and is altogether out of the way of any thing that is experimented on the Pump.

Its lower Orifice is plung'd in a Glass of Mercury describ'd by *m m*, on the Surface of which is laid a Piece of Cork with a Hole in the Middle for the Glass Tube to pass through. On this Cork is placed a Board made of Box Wood, about an Inch in Breadth, and groov'd in the Middle to receive the fore-mention'd Glass Tube, which is loosely loop'd on to the same

ame by two Braſs Loops, that it may have the liberty of riſing and falſing as the Mercury aſcends or deſcends in the Gage. To the upper Part of this Tube is cemented a Braſs Head, which Braſs Head fits into the fore-mentioned perforated Braſs-Piece, that is ſcrew'd on under the Plate, and has a communication, as well with the Recipient on the ſame, as with the hollow Braſs Wire *h h h h* paſſing between the two Barrels. The Box Board is graduated into Inches and Quarters, from the Surface of the Quickſilver to 28 Inches high: From thence 'tis divided into Tenths of Inches.

By this Gage the Degrees of Rarefaction in any Inſtrument are at all times moſt nicely to be obſerved, The Air-Cock *n*, which lets in the Air, is likewiſe a Screw on the ſame fore-mentioned perforated Braſs, in which the upper Parts of the Gage and hollow Wire are inſerted. *f f* here and *o o o o* (*Fig.* 4.) repreſents a Receiver ſtanding on the Place of the Pump, on whoſe upper Part *p p*, thro' a Box of Collars of Leather, paſſes a Slip-wire, whoſe Office is to take up, let fall, or ſuſpend any thing at any determinate Height, in the Receiver, without the Air's Inſinuation. When Motion is to be given to Bodies *in vacuo*, without letting in the Air, the two Pillars K K are to be ſcrew'd on upon the Pump, to hold a Croſs-Board, whoſe Under-Side is arm'd with a Braſs or Iron Plate to receive the upper Part of an Iron Axis, which carries a Pulley *m* fix'd to it to receive a Rope coming from a Wheel, (not repreſented here, but ſuppoſed big enough to give this Pulley a very rapid Motion) from whoſe Frame, Braces K L are carried againſt the Pillars to keep the Pump ſteady. The Axis *g h h* goes thro' a Braſs Diſh *i i* upon the Receiver, which has a Collar of oil'd Leathers with Water at the top, to prevent the Paſſage of Air into the exhauſted Receiver *f f*. *h h* is a Piece to faſten any Bodies to, that are to have a Motion given them. For which purpoſe alſo the Pieces of *Fig.* 31. *Plate* 25. are to be uſed. At other times Receivers like *o o o o* are to be uſed upon the Plate of the Pump.

Mr. *William Vream*, who was my Operator for Philoſophical Machines, alter'd Mr. *Haukſbee*'s Pump ſo as to have the Handle turn round always one way in its Operation, by means of a Crank, which by two leading Pieces gives the Wheel that moves the Racks, a Motion of two Thirds of its Circumference every time the Crank goes round, whereby the Strokes are quicker tho' ſhorter, as may be ſeen in *Figure* 2, and 3.

What Advantages he thought he gave *Haukſbee*'s Pump by it, take in his own Words. After he had copied *Haukſbee*'s Deſcription of his Pump (the Deſcription juſt given) he ſays,

" Thus far Mr. *Haukſbee* has deſcrib'd the Pump; which I hope I
" have ſince improv'd by a Contrivance, whereby in turning the Winch

Lect. XI. " quite round, the *Emboli* or Piſtons are alternately raiſed and depreſſed; " whereas in Mr. *Haukſbee*'s way, the moving of the Hand backward " and forward is not only more troubleſome, but ſhakes the Pump; be- " cauſe it is requir'd to preſs the Piſtons hard againſt the Bottom-piece " under the Barrels to diſcharge the Water from the Valves at every " Stroke. Beſides, if the Pump ſhould at any time happen to leak, when " an Experiment ſhould be made in haſte; you may exhauſt ſo faſt this " way, as to make your Experiment without being at the trouble to " pull the Pump to pieces, in order to make it tight; except in ſuch " caſes, as require the Recipient to be perfectly exhauſted."

Plate 24. Fig. 2, 3.

N. B. The 2d and 3d Figure of *Plate* 24, ſhew wherein *Vream*'s Improvement conſiſts. A W repreſents the Wheel whoſe Teeth take thoſe of the Racks R R, which terminate in Rods that move the Piſtons in the Barrels B B. P *c* is a Leader, whereby the Crank O *c* turn'd by the Handle H (repreſented by C *c c c* H, in *Fig*. 3.) carries the Wheel from the Point P to the Point *o* at every Stroke, ſo as to employ one Third of its Teeth on each ſide, in raiſing and depreſſing the Racks. Here the Racks are ſhorter, and the Wheel bigger than is uſual in *Haukſbee*'s Pumps. *c c c* is the Circle deſcrib'd by the Bend of the Crank that carries the Leader, which Circle muſt always be leſs than that mark'd with Points *q o m*, on the Wheel of which the Pin P at the End of the Leader deſcribes a third; otherwiſe the Crank might jam in its Motions. C *c*, C *c*, and C *c* are three Poſitions of the Crank, and *c o*, *c m*, &c. of the Leader. The Leader conſiſts of two parallel and ſimilar Pieces, taking the Wheel on each ſide; as may be ſeen in *Fig*. 3. where *c* P, *c* P repreſents thoſe Pieces, join'd by the Crank at *c c*, and the Pin at P P with the Wheel W between, whoſe Axis is at A. C C is the Axis of the Crank, and H its Handle.

Here notice is to be taken, that the Receiver of *Fig*. 4. is moſtly uſed upon the Air-Pump, L H repreſenting a Wire which ſlips up and down thro' the Collar of oil'd Leathers at C, with an Hook at H to hold a Body at any Height *in vacuo*, and lift it up and down without Admiſſion of the outward Air. The 25th Plate repreſents many other Receivers, and the Manner of making the Experiments ſuitable to them. What is now on the Pump, is a Receiver, on purpoſe to give Bodies a ſwift Motion *in vacuo*, which we have drawn here upon the Pump, becauſe the manner of fixing it requires a particular Deſcription, which follows:

From a large Wheel at ſome diſtance (not drawn here) comes the Band or String M *m*, which going round the Pulley *m*, makes the Axis of

of it, with whatever is fix'd to it within the Receiver, turn round 20 times at every Revolution of the great Wheel. Now left so swift a Motion should let in the external Air, there are two Pillars K K, K K, screwed to the Pump on the Outside of the Receiver, with a Board, on whose Underside is a strong Piece of Brass to take in the End of the Steel Axis *g h h*, the other End of it bearing on and in a Piece within the Receiver at *k*, screwed to the Plate of the Pump on that occasion. *i i* is a little Dish to hold Water, the better to keep moist a Collar of oil'd Leathers in the middle of it, thro' which the Axis passes, (not drawn here) to keep out the Air. From the Frame of the great Wheel come two Braces against the Pillars K K, K K, to keep all firm, whose Ends only are seen here mark'd L L. N. B. *The Pulley and Axis of this Machine and Spring to hold Flints to strike against Steel* in vacuo, *are represented in the* 31st Figure of Plate 25. *and described in their proper Place.*

EXPERIMENTS *to shew the Expansion of the Air, by its* Spring, *or* Elasticity.

1. TAKE a Bladder and squeeze out the Air, so as to leave only what remains in the Folds of the Bladder; then tie it close and seal it, so that the Air cannot escape. Lay the Bladder on the Air-Pump, and set a Receiver over it; then exhaust the Receiver, and the Air in the Bladder will expand it self so as to blow up the Bladder; when you let in the Air, the Bladder will return to its former Shape: Which shews the Expansion of the Air by its Spring or Elasticity. *Plate* 25. *Fig.* 1.

2. To know how much the Air expands it self, take a Glass Bubble, of about an Inch Diameter, with a Stem of about six or eight Inches, fill it almost all full of Water, except a very small Bubble of Air; then inverting this Bubble or Bolt-Head into a Jar of Water, cover the whole with a Receiver, which exhaust, and the little Bubble of Air will expand it self: So that by comparing the Bigness of the said Bubble of Air as it was at first, to its Bigness when expanded, you will know the Proportion of the Expansion of Air. *Plate* 25. *Fig.* 2.

3. TAKE an Egg and break off evenly about a third Part of the Shell at the little End, and put the Yolk and White out of the Shell, and at the bottom you will see a small Bubble of Air, which lies between the Skin and the Shell; set the Egg up in some little open Glass on the Pump, and put a small Receiver over it, and when you exhaust the Receiver, the Air in the Shell will expand it self, and raise up the Skin, so as to fill the Shell, and appear like a whole Egg. Or take an Egg and make a small Hole in the little End, and invert it in a small Glass, and set it on

Lect. XI. the Plate, and set a Receiver over it, and when you exhaust the Receiver, the Air in the Bubble will expand it self, so as to force all the Egg out of the Shell through the Hole in the End; then let in the Air, and if the Shell be kept down, it will all return again into the Shell; which likewise shews the Expansion of the Air by its Spring. *Plate* 25. *Fig.* 3.

4. Take the Flint-Glass Bottle with the Brass-Head, and put a little Mercury in the Bottom, then take the long small Tube which is made for that purpose, and screw it into the Hole, so that the End may almost touch the Bottom of the Bottle; then setting the Receiver with the large Tube, to cover the small one over Bottle and Tube, as you exhaust it you will see the Mercury rise in the Tube, according to the Expansion of the Air in the Bottle, which (when the Receiver is quite exhausted) will stand at the Height of the Mercury in the common Barometer. *N. B.* The small Tube must be open at both Ends.

N. B. *If you compare the Height of the Mercury in the Gage under the Pump, with the Height of the Mercury in the Tube of the Bottle abovesaid, they will appear to be of the same Height, which shews that the Spring of the Air is just equal to the Pressure of the Atmosphere.* Plate 25. Fig. 4.

5. Take Glass Bubbles and hollow Glass Images, so far fill'd with Water as to make them sink in a Jar of Water, the whole being set under a Receiver; and upon drawing out the Air the Bubbles and Images will rise up to the top of the Water, but sink down again as you let in the Air. *Plate* 25. *Fig.* 5.

6. The same Experiment may be made by a Bladder half fill'd with Air, and just sunk with Weights.

7. Take a Bladder and squeeze out some of the Air, so that it will go into a wooden cylindrick Box, then lay a Plate of Brass over the Bladder, and screw a Wire into the Middle of the Plate, about 9 Inches high, lay on that Plate Lead-Weights, of what Weight you please, with Holes in the Middle to receive the Wire; put it on the Pump with a large Receiver over it all, then the Receiver being open at the top, lay on a wet Leather and a Plate of Brass, with a Piece of hollow Wire in the Middle to receive the Wire in the other Plate, and to go also into the Holes of the Weights; then exhaust the Receiver, and the Air in the Bladder will expand it self, and raise up the Weights, though you have above forty Pounds; then let in the Air, and the Weights will come down as before. *Plate* 25. *Fig.* 6.

8. Take a small Tube, about five Inches long, and cement it into a Brass Screw, which will fix it to the Bottle which you use for raising the Mercury; then tie a small Bladder upon the End of the Tube which goes

into

into the Bottle, and ſeal it tight, ſo that the Air cannot eſcape any where but through the Tube: ſqueeze the Bladder together, and having put it through the Screw-Hole into the Bottle, ſcrew the Braſs Screw with a Leather upon it, tight into the Bottle, having firſt blown up the Bladder within the Bottle before you fix the Screw, ſo make it tight with a Key, and ſet the Machine on the Pump with a Receiver over it. When you begin to exhauſt, the Air in the Bottle will expand it ſelf, and preſs the Bladder together, which ſhews how the Lungs of an Animal *in vacuo* are preſſed together by the Expanſion of the Air in the *Thorax*, becauſe the Lungs having a correſpondence with the Receiver through the Wind-Pipe, have no Air in them in ſuch a caſe, to keep up the Lungs againſt the Expanſion of the Air in the Cavity of the *Thorax*, which preſſes againſt the Outſide of the Lungs; as the Air in the Bottle in this Experiment cauſes the contain'd Bladder to ſubſide *in vacuo*. *Plate* 25. *Fig.* 7. Lect. XI.

9. CATS, or other Animals, die *in vacuo*, if the Air is not let in again very ſoon.

10. FISHES put in a Jar of Water under a Receiver, will (when the Receiver is exhauſted) riſe up to the Top of the Water, without being able to go down to the Bottom, becauſe the Air in their Wind-Bladder being expanded againſt their Will, makes them ſpecifically lighter than Water: Sometimes the Bladder breaks, and then they ſink down to the Bottom, whence they can riſe no more. *N. B.* Fiſhes, Frogs, *and other Animals that live in the Water, will not die by exhauſting the Air from the Receiver, unleſs they be kept many Days* in vacuo.

11. TAKE a ſquare Phial, and put in a Cork, then ſeal it ſo that no Air can eſcape, and put it into a Cage of Wire; then ſet it on the Pump with a Receiver over it, and when you begin to exhauſt, the Air in the Bottle will expand it ſelf ſo as to break it. When you have made this Experiment, wipe the Leather and your Pump-Plate, ſo that none of the Glaſs remain, for it may ſpoil another Experiment. *Plate* 25. *Fig.* 8.

12. THE ſame Experiment is to be made with the Bottle and Cage under Water, in which caſe the Shock will be ſo great as to ſhake the whole Pump. *Plate* 25. *Fig.* 9.

N. B. *The Uſe of the Cage is to hinder any large Piece of the broken Bottle from ſtriking againſt the Receiver, which might endanger its breaking.*

EXPERIMENTS

Lect. XI.

EXPERIMENTS *to shew the* SPRING *of the* AIR *in the Pores of Bodies.*

13. TAKE an Apple as much shrivelled as can be had, and lay it on the Pump, set a Receiver over it; as you exhaust the Receiver, the Apple will appear as smooth as one fresh gathered, let in the Air, and it will return to its former Shape.

14. TAKE a small Jar or Cup, and fill it almost full of small Beer, then taste it and set it on the Pump, and put a Receiver over it, and when you exhaust the Receiver, the Air in the Beer will expand it self, and cause the Beer to rise up in a Froth, so as to come quite over the Glass: Then let in the Air and taste the Beer, and you will find it quite dead. N. B. *If, instead of a Tumbler or common Drinking-Glass, your Beer be put in a tall cylindrick Jar about* 20 *Inches high, a curious Observation may be made, which is this: After having pump'd out most of the Beer from the Receiver, you will observe Bubbles of Air to rise from the Bottom of the Beer, and come up to the Top, increasing their Diameters as they rise, but without joining with other Bubbles in the way. You may observe several of them to be very small in Diameter at their first Appearance, and when being got to the Top of the Beer they are freed from the Pressure of a Pillar of Liquor about* 20 *Inches high, they appear to be increas'd at least* 10 *times in Diameter. This shews how much the Air is rarefied in that Receiver,* viz. *at least* 1000 *times; because as Spheres are to one another as the Cubes of their Diameters, it is plain that all such Bubbles are expanded or rarefied* 1000 *times.*

15. TAKE a small Jar or Cup, and fill it with luke-warm Water, and set it on the Pump with a Receiver over it, and when you exhaust the Receiver, the Air in the Water will expand it self, and raise large Bubbles, so that the Water which was luke-warm will seem to boil, and diffuse its Heat so as to warm the Receiver all over; then let in the Air, and it will immediately cease to bubble.

16. TAKE a Piece of Cork, and fix to it a Piece of Lead, so as to poise the Cork, that it will but just sink in Water; then take a Glass Jar full of Water, and put in the Cork and Lead, which set on the Pump with a Receiver over it, and when you begin to exhaust, the Air in the Pores of the Cork will expand it self so as to swell the Cork, which therefore becoming lighter than an equal Bulk of Water, will rise up to the Surface; then let in the Air, and the Cork will sink to the Bottom again. *Plate* 25. *Fig.* 10.

17. TAKE boil'd Water, and after having drawn as much Air out of it, as can be done by the Pump, put a Piece of raw Flesh into the Water, and

and you will find that upon pumping out of the Air, that Air that was contain'd in the Flesh will extricate itself in time, bubbling up through the Water. Lect. XI.

N. B. *There is Air in* Blood *and all* animal Fluids.

EXPERIMENTS *to shew the Pressure of the Air.*

18. TAKE a Glass open at both Ends, of about two Inches Diameter, and of what Height you please, set it on the Pump, then lay on your Hand so as to cover the Glass, and begin to exhaust, and you will feel the Pressure of the Air; for the Air being taken from under your Hand out of the Glass, the external Air will press your Hand to the Glass, so that you can scarcely move it; upon letting in the Air, it will be loosen'd again.

N. B. *The* Spring *of the* Air *in your Flesh is also shewn by this Experiment, the Flesh of the Inside of your Hand swelling downward within the exhausted Glass.*

19. TAKE a Glass which is open at both Ends, then take a Bladder, and wet it well, stretch it over the largest End of the Glass, which must be at least four Inches wide, then tie it, and let it dry on, and when it is dry, set it on the Air-Pump, with the Bladder uppermost; then exhaust the Glass, and the external Air will break the Bladder with a large Report. *Plate* 25. *Fig.* 11.

20. TAKE a Piece of common Window-Glass, and lay it upon the Mouth of a Receiver, or Brass Ferril, and set it on the Air-Pump; exhaust the Receiver, or Brass Ferril, and the external Air will break the Glass all to pieces, in the same manner as the Bladder in the other Experiment.

21. TAKE a square Bottle, and cement on a Cap of Brass, with a Place for a Valve, then tie a small Piece of wet Bladder over the Hole, so that the Air can come out, but cannot return the same way; then put it in the Cage of Wire, and set it on the Air-Pump with a Receiver over it, and when you exhaust the Receiver, the Air in the Bottle will come out thro' the Valve: When you have quite exhausted the Receiver, then let in the Air on the sudden, which not being able to get into the Bottle, because of the Valve, it will break the Bottle all to pieces. *Plate* 25. *Fig.* 12.

22. TAKE a couple of Brass Hemispheres, and set them upon one another, with a wet Leather, (which has a Hole in the Middle) in order to make them tight, and having screw'd a Cock into one of them, fix them to the Pump by means of a double Male Screw, always observing to have oil'd Leather between the Screws; when you have exhausted the Hemispheres,

Lect. XI. Hemiſpheres, turn the Cock to ſhut their Communication with the Pump: Take off the Hemiſpheres, and they will ſtick ſo faſt as to require a Force to pull them aſunder, about 140 Pound; if their Diameter be equal to $3\frac{1}{2}$ Inches, and proportionably more or leſs, according to their Diameters, the Weight requir'd to draw them aſunder being greater or leſs, juſt as the Square of the Diameters of the Hemiſpheres is greater or leſs than the Square of three Inches and a half, in which caſe the Weight is 140 Pound.

N. B. *You muſt ſcrew two Rings to the exhauſted Hemiſpheres, and draw them aſunder with a ſtrong Steelyard.* See *Fig.* 28.

THE exhauſted Hemiſpheres will fall aſunder of themſelves *in vacuo*, if you fix the uppermoſt to the Hook of the ſlip Wire before you exhauſt. In the 13 *Fig. of Plate* 25. you ſee the Hemiſpheres exhauſted *in vacuo*, the wooden Diſh made uſe of for the Bladder, in the 7th Experiment, being ſet under to receive the falling Hemiſphere, leſt it ſhould damage the Glaſs.

23. TAKE the Plate of your *Transferrer*, (which is a ſix-Inch Plate) and having by means of its Cock fix'd it to the Pump, ſcrew a ſpouting Tube to the upper Part of it, at the End of the Cock's Screw, which comes thro' the Plate. Put a wet Leather upon the Plate, and then ſet upon it the talleſt Receiver you have. Exhauſt it, and having turn'd the Cock, take it off of the Pump. Hold this exhauſted Machine over a Baſon of Water, and having put the Mouth of the Cock under Water, open the Cock, and the Atmoſphere will, by its Preſſure, force the Water up into the evacuated Receiver, making a pleaſant Fountain. *Plate* 25. *Fig.* 14.

24. HAVING exhauſted the tall Receiver above-mention'd, and taken it from the Pump, take a pretty large Glaſs Fountain, or Braſs one, with its Force-Pipe ſcrew'd into it, but without its *Ajutage*, (or Spouting-Pipe) let this Fountain be half full of Water, (no Air being condens'd over the Water) and having ſcrew'd the Cock of the Plate to it, turn the Cock, and the Air in the Fountain will by its Spring preſs ſo hard upon the Water under it, as to cauſe it to riſe through the Force-Pipe quite into the exhauſted Receiver, ſpouting up in a pleaſant manner as before. *Plate* 25. *Fig.* 15.

25. TAKE a pretty tall open Receiver, and having ſet a Gally-pot half full of Mercury upon the Plate of the Pump, take the four Inch Plate, and ſcrew it to the Glaſs Tube that has a double Male Screw faſten'd to the End of it, ſo that when the Plate (with a wet Leather under it) is ſet upon the Receiver, the End of the Glaſs Tube may dip into the Mercury in the Gally-pot. Then ſcrew the little Syringe upon the

the upper Screw of the ſaid Tube, above the Plate and Receiver. Gently lift up the Piſton of the Syringe, and you will ſee the Mercury riſe out of the Gally-pot into the Glaſs Tube; afterwards exhauſt the Receiver as much as you can, and when no Air is left in it, you may then pull the Piſton of the Syringe quite up, without ſucking any Mercury up the Glaſs Tube. This ſhews that all the Phænomena of Suction and Pumps, are not owing to an Abhorrence of a Vacuum in Nature; but to the Preſſure of Air. *Plate* 25. *Fig.* 16.

26. TAKE a Lamp Cupping-glaſs, and ſet it on the Pump, with a Receiver (that hath a ſmall Hole in the Top) over it, then exhauſt the Receiver, and the Air in the Cupping-glaſs will expand itſelf, and come out. Then let in the Air on the ſudden by taking off your Finger, which was held at the top Hole of the Receiver, and the Cupping-glaſs will be faſt, and the Receiver become looſen'd. Put on the Receiver, and exhauſt again, and the Cupping-glaſs will be looſe, and the Receiver faſt, as at firſt; but you muſt not ſet the Cupping-glaſs over the Hole in the Plate, becauſe then you would exhauſt that, and not the Receiver. This Experiment ſhews, that what is commonly call'd Suction, is only the Preſſure of Air, which faſtens the Cupping-glaſs by ſtriking againſt the Outſide of it, before it can get under it. *Plate* 25. *Fig.* 17.

27. TAKE two *Glaſs-bubble Fountains*, (that is, Glaſs-bubbles of about two Inches Diameter, with a Tube ſo cemented in the Neck of each of them, that one End almoſt touches the Bubble on the Inſide, and the other End, without the Bubble, is almoſt all ſhut up but a ſmall Pin-hole) and invert the one into a little Jar of Water, and the other into a Jar of Mercury; then ſetting all under a Receiver, upon exhauſting it, the Air will by its Expanſion come out of the Fountains, through the Water and Mercury. As you let in the Air again, it will force up thoſe Fluids into their reſpective Fountains; which being afterwards ſet with the right End upwards in a tall Receiver, will, upon exhauſting it, make Jets of Water and of Mercury, by the Spring of the Air above the Mercury or Water, in the Bubbles. N. B. *You muſt not quite exhauſt the firſt Receiver, leſt too much Mercury or Water ſhould be forc'd into the Fountain.* *Plate* 25. *Fig.* 18, 19.

28. TAKE a common Barometer Tube, and fill it with Mercury, and invert it in a little Mercury in a Cup or Jar; then ſet it on the Air-Pump, and ſet a Receiver over it, open at the Top; then lay a wet Leather on the Top of the Glaſs, and take the large Tube, mention'd in the fourth Experiment, with a Cap and a Plate cemented on at the one End, hermetically ſeal'd at the other, and put it over the other Tube with the Mercury, ſo as to be tight with the Receiver; then begin to

 exhauſt,

Lect. XI. exhaust, and the Mercury in the inner Tube will come down in the same Proportion as that in the Gage rises. If your Pump be tight, you may bring it quite down, so as to be even with the Surface of the other Mercury. Then let in the Air very gently, for if you let it in too fast, you will endanger breaking the Tube, and spoil the Experiment.

29. Take two Pieces of Marble, Planes of Glass, or Plates of Brass well polish'd, then put a little Oil between them, to keep them from admitting the Air between them, and the lowest Marble will stick so fast to the uppermost, as to hold a considerable Weight; then take a Receiver, open at both Ends, and set it on the Air-Pump, lay a wet Leather on the Top thereof, and take the Brass Plate, with the Collar of Leathers and Slip Wire, and screw on a Hook, put the Plate upon the Top of the Glass, and hang on the Marbles or Plates on the Hook within the Glass, then exhaust the Receiver, and they will drop asunder; then let down the upper Piece just upon the under, and let in the Air on the sudden, and then the Marbles when taken out of the Glass, will bear more Weight than before, when you had put them together with your Hands. The same Receiver, Plate, and Wire will serve, as used in the 22d Experiment. *Plate* 25. *Fig.* 13.

30. Take a small Syringe, with a Lead Weight at the Bottom, then take a tall Glass, and set it on the Air-Pump, and lay a wet Leather on the Mouth thereof, then take the three Inch Plate with the Collar of Leathers, and Wire, and screw the End of the Wire into the Top of the Syringe, which put within the Glass, with the Lead Weight at the Bottom; then exhaust the Glass, and the Weight will come down with the Barrel of the Syringe, because the Air being taken out of the Receiver, which press'd upon the Piston of the Syringe, the Weight becomes too heavy for the Friction of the Piston's Leather against the Sides of the Syringe, and not being resisted by the Air, it must by consequence come down; let in the Air, and the Weight rising again will return to its former State. *Plate* 25. *Fig.* 20.

Miscellaneous Experiments.

31. Take a middle-siz'd Glass, wipe it well, and set it on the Plate; then begin to exhaust a little, and hold a Candle on the other Side, and you will see a *Halo* about the Candle, or several Colours in the Glass; which will be seen only when the Glass is first exhausting, for when the Glass is quite exhausted, the Colours are all lost. But if you let in the Air, and begin to exhaust, you will see the Colours as before, which may be repeated as often as you please. *Plate* 25. *Fig.* 21.

32. Take a tall Glass, set it on the Air-Pump, and lay a wet Leather

Leather on the Mouth thereof; then take the three Inch Plate, with the Collar of Leathers and Wire, and ſcrew on the Braſs Springs with the Flap at Bottom, and a Slip-Plate to open the Spring when *in vacuo:* Screw the Slip-Plate to the Wire, then put a piece of Gold, or what Metal you pleaſe, with a Feather or a bit of Paper, upon the Flap of the Springs under the Slip-Plate, and exhauſt the Receiver quite. Then looking into the Receiver at bottom, pull the Wire to open the Springs, and let fall the Gold and Feather, which will come juſt at the ſame time to the Bottom, becauſe the Air being taken away, which made the Reſiſtance, all Bodies fall equally faſt. *Plate* 25. *Fig.* 22. Lect. XI.

Mr. *John van Muſchenbroek*, Brother to the Profeſſor at *Leyden*, contriv'd a Method whereby five or ſix Pieces of Gold, and as many Feathers with them, might be let fall one after another, without making a new Exhauſtion, which is very convenient when a very tall Receiver, ſimple or compound, (that is, made up of ſeveral Glaſſes ſet upon one another) is made uſe of, becauſe it is a long while in exhauſting. The Draught and Deſcription of it is to be found at the End of the ſecond Volume of the Profeſſor's *Eſſays de Phyſique*, printed at *Leyden*, 1739.

33. Set your Bell upon the Plate of the Pump, and cover it with a middle-ſiz'd Receiver, then ſhake the Pump, and take notice of the Sound of the Bell. Exhauſt the Air, and you will not hear the Sound *in vacuo*, though the Clapper is made to ſtrike the Side of the Bell. *N. B.* The Bell muſt be ſet on a little Cotton Pillow, or ſome ſoft Body, otherwiſe you will ſtill hear a little Sound.

34. Set a lighted Candle in your talleſt Receiver, and a few Exſuctions will cauſe the Candle to go out. The Smoak of the Candle will then lie at the Top of the Receiver, but when you have pump'd out all the Air it will fall down. This ſhews that the Smoak does not riſe, becauſe it is poſitively light; but only becauſe it was ſpecifically lighter (or leſs heavy) than Air.

35. A Piece of lighted Charcoal, fix'd by a Wire to the Braſs Hook belonging to the Collar of Leathers, ſo as to ſuſpend it in a Receiver, will go out *in vacuo*.

36. When you would fire Gunpowder *in vacuo*, take a Gally-pot, and inverting it, ſet the Gunpowder Iron (that you have with the Pump) upon the Pot, having firſt made it red-hot. Cover it with your Gunpowder Receiver, (which muſt be firſt warm'd by Degrees, leſt the Heat of the Iron ſhould crack it) and having exhauſted it, by moving the Slip of Wire up and down, you will let fall a ſmall Quantity of Gunpowder upon the hot Iron, where it will fire, Corn by Corn. When you let in the Air again, let it be by little and little, leſt you crack the Receiver.

Lect. XI. N. B. *After every Explosion exhaust the Receiver, because the Gunpowder generates Air, and might at last burst the Receiver.* *Plate* 25. *Fig.* 23.

37. If you would preserve Fruit, Flowers, or any thing else *in vacuo*, fix the Plate of your Transferrer by its Hook to the Pump Plate, on which you may lay your Fruit in a Jar: Cover the whole with a Receiver, that stands on the Transferrer with a wet Leather under it. After Exhaustion take off the Receiver, as is mention'd in the 24th Experiment, and keep it as long as you will, having screw'd the Cock to its wooden Foot. If you would prevent the least Air from coming in, put the whole Machine under Water, and keep it so. *Plate* 25. *Fig.* 24.

38. Take the Steel Plate *h h*, *Plate* 25. *Fig.* 25. which is fix'd on the Spindle *g p*, with the Nuts belonging to the Machine for the Attrition of Bodies *in vacuo*, (*which is represented in Plate* 24.) and having screw'd the Brass Springs with the Flints tied to them at H H, so as to press the Edge of them against the Steel, let the Spindle below the Pulley *m* pass through the Collar of Leathers of the Plate, which covers the large Receiver, that is set over the Flint and Steel: Put the Pulley and String upon the Spindle, and screw down the Board with the Center Hole cross the Pillars; then turn the great Wheel to give a Motion to the Steel Plate against the Flint, which will produce many Sparks; but as you exhaust the Receiver, the Sparks will diminish, and quite vanish when all the Air is drawn out, though the same violent Motion is continued. *Plate* 25. *Fig.* 31. represents the Brass Springs with the Flint fix'd to them, and the Hole to screw in the Center Plate for the Spindle to turn upon. The same Figure also represents the Spindle and Pulley, with the Steel Plate and Nuts in the Middle. N. B. *The Hole of the Brass Springs screws on the Piece that receives the End of the Axis* P, *or the Plate of the Air-Pump.*

39. Soap'd Water will rise into large Bubbles *in vacuo*, upon which you will see several Colours succeed each other; and the Skin of Water, when extremely thin, will be black.

40. With a Piece of solid Phosphorus write upon a Paper, and laying it upon the Plate of the Pump with another Paper under, (lest you wet the first Paper) draw out the Air, and the Phosphorus will brighten by degrees, and at last throw up a lucid Cloud to the Top of the Receiver. N. B. *The Room must be dark for such kind of Experiments.*

41. If you wet the Paper by Patches on which you have drawn Lines with Phosphorus, instead of a Cloud, it will give Flashes *in vacuo*.

42. Take the Receiver used for the Guinea and Feather Experiment, and to the Brass Plate, used to cover it, screw a large Cupping-glass with a Tube cemented to its Neck, with a fine Hole in it, (so as to make a Funnel)

Funnel) and having ſtopt the Hole of the Neck of the ſaid Cupping-glaſs with a wooden Plug, fill it with Mercury. Under the Receiver have another tall one of an arch'd Figure without a Knob at top, as in *Plate* 25. *Fig.* 25. Then having drawn out the Air from both Glaſſes, take out the wooden Plug, and the Weight of the external Air will force the Mercury in a Shower upon the inward Glaſs, ſo as to produce a great Light in a dark Room, if the Mercury be fine, and the Weather very dry, otherwiſe the Experiment will not ſucceed.

43. Having cemented an open Tube, ending in a Point, to a Braſs Stop-Cock, put it through the Braſs Plate that covers an open Receiver, ſo that the Tube ſhall reach down half an Inch below the Surface of about a Pound or two of Mercury in a Glaſs Jar under the Receiver. Shut the Cock, then exhauſt the Receiver, and then opening the Cock the Air will ruſh in, through the Mercury, ſo as to throw it in little Balls all over the Glaſs, and produce a fiery Shower, viſible in a dark Room if the Weather be dry. *Plate* 25. *Fig.* 26.

44. Having exhauſted a Receiver, let in the Air again at top, through an Iron Tube, (or Braſs Tube, whoſe End is ſcrew'd to an Iron one) ſo that it may paſs through the Flame of Charcoal, before it goes into the Receiver; and when the Receiver is full of that Air, lift up the Cover of the Receiver, and letting down an Animal into the Glaſs, you will find that this infected Air will kill him immediately. If the End of the Tube be thruſt into the Hole of a ſolid Piece of red-hot Braſs, which is not perforated quite through, the Air which muſt come into the Tube, will in its way carry along with it the *Effluvia* of the Braſs, which will poiſon the Air, but not ſo much as before, an Animal being longer a dying in this than in the laſt Medium. If a Candle be let down into the Receiver, when fill'd with this Air, it will go out, but purge the Air as far as it goes; for you may let it down the ſecond time lower than the firſt, and ſo on, till the whole Air be purify'd. N. B. *Air burn'd in going through red-hot Iron or Copper, is not pernicious to a very tender Bird, or any Animal, that it has been try'd upon. See Plate* 25. *Fig.* 27.

45. To an equal (but ſmall) Quantity of Oil of Vitriol, Oil of Tartar *per Deliquium*, and Oil of Cloves, put two or three ſmall Pieces of Phoſphorus, and this Mixture will take Fire in the open Air, but the Addition of a little common Water will put it out. This Preparation will not only ſhine, but boil up into a Flame, in the exhauſted Receiver.

46. If you would weigh any Quantity of Air, take a pretty large Copper or Glaſs Ball, ſuch as Fountains (by Compreſſion of Air upon Water) are made of, and having, by means of a Cock fix'd it to the

 Female

Lect. XI. Female Screw in the Plate of your Air-Pump, exhaust it; shut the Cock, and having taken off this exhausted Ball, hang it at one End of the Beam of a Pair of Scales; counterpoise it at the other End; then let in the Air into the Ball, by opening the Cock, and the Ball will preponderate: So much Weight being requir'd to restore the *Æquilibrium*, as answers to the Weight of the Air contain'd in the Ball above-mention'd. *This was done in the first Lecture of Hydrostaticks*, see *Plate* 8. *Fig.* 10. L. 7. N° 3.

47. To the slip Wire of the Collar of Leathers, at the Top of a Receiver, fix a Piece of Cork, with several small Tubes going through it, and having set a Jar with colour'd Water in it, under the Receiver, pump out the Air; then by pushing down the slip Wire, plunge the Ends of the small Tubes into the colour'd Water, and it will rise as high in those Tubes as it does in open Air. N. B. *This was done in the first Lecture of* Vol. I.

48. Take a Vessel of Brass, like a Funnel, or truncated Cone, open at both Ends, made so that the Hole at one End is not above 1 $\frac{1}{4}$ Inch Diameter, and the other End almost four Inches. Set this truncated Cone upon the Receiver with the small Hole upwards, and having laid a Piece of flat Window Glass upon it, exhaust the Air, and the Glass will not break: Let in the Air again, and laying the same Piece of Glass upon the larger Orifice of the Brass Vessel, as soon as you have drawn out the Air, it will break; which shews the Pressure of the Air is proportionable to the Surface on which it presses. The Brass truncated Cone is shewn by *Fig.* 29. *Plate* 25.

49. Flies will not die, but be unable to fly *in vacuo*.

50. Take a Piece of Wood with a little Hollow in it, like a round Trencher, and weigh it; then having laid some Mercury in the said Hollow, cover it with a Receiver; and when you have drawn out, and again let in the Air, you will find the Wood much heavier than it was, the Air having press'd a great deal of the Mercury into the Pores of the Wood. *Plate* 25. *Fig.* 30.

Of the Artificial Condensation *of Air*.

We have shewn that Air may be rarefied and condens'd naturally and artificially; and have given Instances of its Rarefaction by Art in 50 Experiments: now we will shew some Experiments of its Condensation by Art, and observe the Phænomena arising from thence.

One of the chief Instruments for condensing Air is a Syringe, such as is represented by the 11th Figure of *Plate* 21. There indeed it is made use of for the Rarefaction of Air; but as only inverting its Piston makes it fit for Condensation, we must here give a Description of the Piston, as it

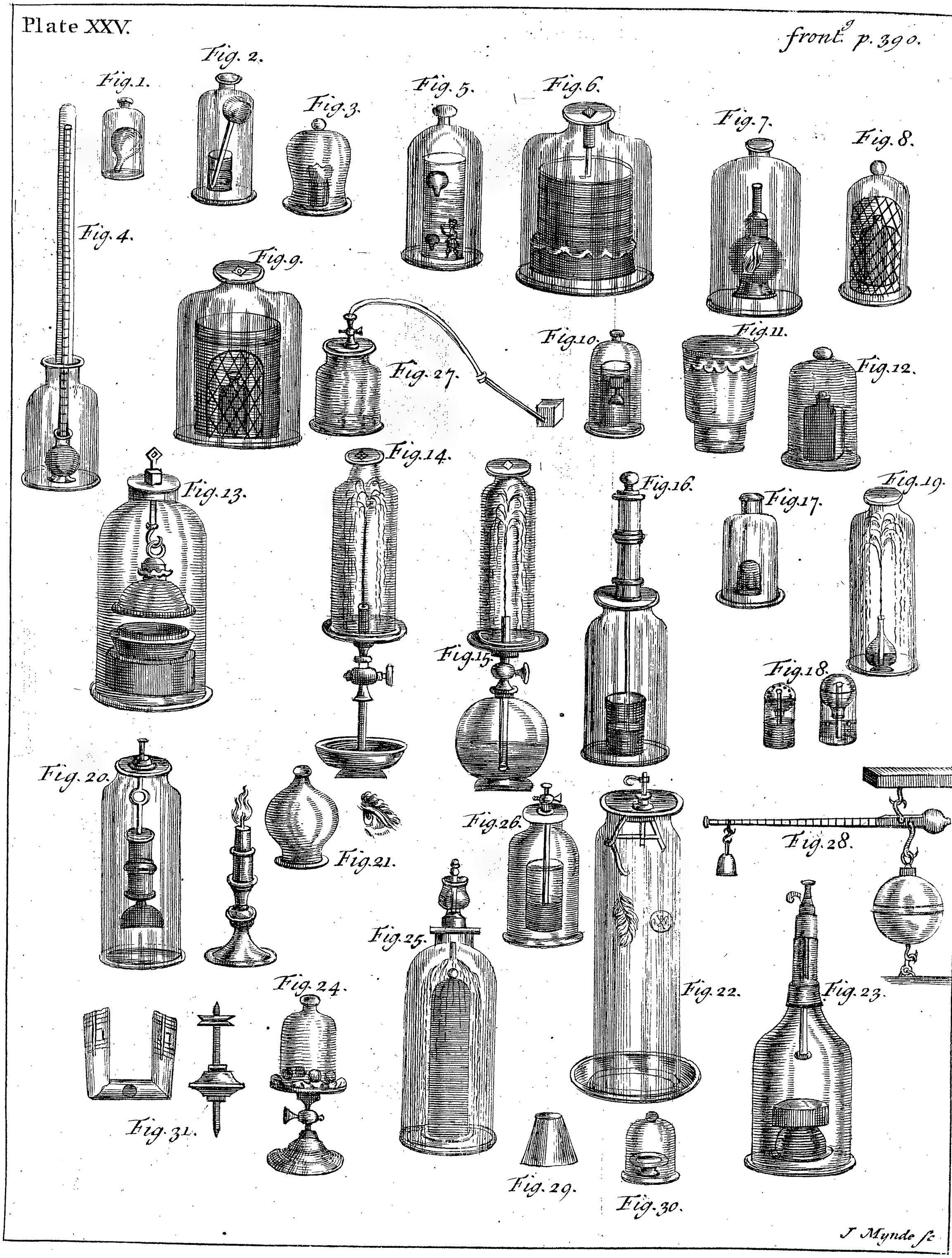


Plate XXV.
front.^g p. 390.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 21.
Fig. 22.
Fig. 23.
Fig. 24.
Fig. 25.
Fig. 26.
Fig. 27.
Fig. 28.
Fig. 29.
Fig. 30.
Fig. 31.
J Mynde sc

it is when applied to either of thoſe Uſes. The 5th Figure of *Plate* 24. Lect. XI.
A B C D repreſents a little Cylinder of Braſs about $\frac{1}{4}$ of an Inch thick, and of a Diameter juſt to move up and down in the Syringe without ſtopping any where, but ſo cloſe as not to admit a thin Paper between. It has a Screw at top and bottom of the ſame Bigneſs, and of the ſame Thread, but with this Difference, *viz.* that at the End C there is a thin Piece of Bladder tied on, which makes a Valve ſo fix'd, as to ſuffer all the Air coming in the Direction D C to paſs by, but ſtop all that coming from C endeavours to go to D. The Rod of the Syringe, whoſe End is repreſented at R, *Fig.* 6. has a Piece like a Bell P P *l l*, with ſmall Holes coming thro' its upper Part, and a female Screw at bottom, to receive the End D of the Screw of *Fig.* 5. That Piece being ſcrew'd in, as mark'd with the ſmall Letters *a b c d*, there muſt be another cylindrick Piece *g g*, whoſe Diameter is about $\frac{1}{30}$ of an Inch ſmaller than the other ſcrew'd on to C, or *c*; ſerving for two Uſes, the one to preſerve the Valve at C from being damag'd againſt the Bottom of the Syringe by its Thickneſs; and the other, (which is its principal Uſe) to preſs a ſoft oil'd Leather *f f* againſt *a b*. This Leather will never fold upwards for want of room between A B and the Sides of the Syringe, but will ſpread againſt them and A B, ſo as to drive all the Air before it (which Air is alſo ſtopp'd by the Valve at C) forward thro' the Noſe of the Syringe into any Place where it is intended to be driven. But when the Rod is drawn up, as the Leather *f f* folds eaſily about the ſmaller cylindrick Plate *g g*, the Air will eaſily paſs by to fill the Syringe that way, as well as thro' the Valve in the Direction *d c*. N. B. *When the Syringe is made uſe of for ſucking, you muſt only invert the Piece* A B C D, *ſo as to ſcrew the End* C *with its Valve into the Ball* P P *with the ſoft oil'd Leather* l l *between, and then the reverſe will happen of what we juſt mention'd; for then in driving down the Piſton the Air from any Veſſel coming into the Syringe, will ſlip in the Direction* a l, b l, *between the Bell and Sides of the Syringe,* (*the Leather* f f *not being on now*) *and alſo thro' the Valve-Piece, and the Holes near* P P: *but in drawing up the Valve will ſhut, and the Leather* l l *will apply cloſe to* a b, *ſo as to admit of no external Air to go back into the Syringe.*

Plate 24. Fig. 5, 6.

In both Caſes, whether of injecting, or exhauſting Air, ſuch a double Screw as A B C D, *Fig.* 5. with its Valve, is to be made uſe of; but with the Valve towards the Rod in ſucking; and the other way in forcing, that no Air injected into any thing ſhould return into the Syringe.

Expe-

Experiments *of Condensation of Air.*

Experiment I.

Plate 24. Fig. 7. From the Pin *l* hangs a Chain of Bladders *a*, *b*, *c*, communicating with each other with an Hook at bottom holding a Weight, as P, upon a Table. To this Chain of Bladders communicates another large Bladder A, holding by an Hook at bottom a Weight W, equal to P upon the same Table. D and E are the two Ends of a Pipe to apply the Mouth or Syringe to, in order to raise the Weights W, P, by driving in Air; and C is a Cock to admit of, or cut off the Communication between the single large Bladder, and the Chain of Bladders upon occasion. Keeping the Cock shut, blow in at D, and the Weight W will rise; but that will be slowly, because the Bladder, by whose swelling it rises, will be long a filling. Then blowing in at E the Weight P will rise, but very soon, because it takes up but a little Breath to fill the Chain *a*, *b*, *c*. Then if the Cock be open'd, and either the End D or E be shut, if you blow at the other End, the Weights W P will rise both slowly, but to the same Heights. This Experiment is made use of in order to explain, or rather illustrate muscular Motion; for all that has been said upon it, tho' several have wrote upon the Subject, does not yet amount to a Demonstration. Those that would explain muscular Motion by a Chain of Bladders reason thus——It is well known that the Muscles having their Origin in one Part, and their Insertion in some Limb or Bone, bring that Limb towards the Origin, when the Belly of the Muscle swelling, the Muscle is shorten'd by its Contraction: and as this is done by the Power of the Will, (and as it were instantaneously) there must be some fine, but powerful Fluid at our command, which they call *Animal Spirits*, suppos'd to be separated from the Blood; (the Existence of which they would confirm by the Consideration of the Steam of boiling Water working in the Engine to raise Water by Fire, where Water, a Fluid of near the same specifick Gravity as Blood, by an Heat not much greater, is rarefied 14000 times, and acts with a prodigious Force, tho' above 16 times lighter than Air:) this they suppose to be driven into the Cavities of the muscular Fibres, which they suppose made up of Chains of little Bladders, (by the Power of the Will) which must contract every Fibre, and consequently the whole Muscle, *&c.*———That by supposing the Bladders Chains, a small Quantity of the Fluid will act speedily, and with the same Force as a larger Quantity, according to the Experiment abovemention'd; and this without too much altering the Shape of the Limbs, *&c.*——That there are lateral Communications from one Fibre to another, without

without which, in case of Wounds, too many fix'd Points would be lost, Lect. XI. &c. but Anatomy not being my Business at present, I must refer those that like the Hypothesis of the Chain of Bladders to those who have defended it; especially to a Dissertation of the late learned Dr. *Alexander Stuart*, who has said as much or more than any body upon that Hypothesis, and whose Work was so well thought of by the Gentlemen of the Academy of *Bourdeaux*, that they gave him the Prize for it in the Year 1740.

THE Doctor shew'd a good deal of Learning, and bestow'd a great deal of pains in that Dissertation; but I think was wrong in denying Repulsion to be a Principle in Nature. He considers it as an Effect flowing from Attraction; but if he had read Sir *Isaac Newton*'s Opticks, and Dr. *Hale*'s Vegetable Staticks, with sufficient Attention; or consider'd several Phænomena, which entirely depend upon that Principle, he would not have fallen into that Mistake. There is also an Experiment that does not seem to agree with the Chain of Bladders, which is this. A long Glass Cylinder big enough to admit of a Man's Arm from the Shoulder upwards, but ending at top in a small Tube, has been closely join'd to the Arm of a Man of strong Muscles, with the small Tube coming beyond the Hand. This Glass Machine being fill'd with Water, quite up into part of the small Tube, the Man clenching his Hand contracted his Muscles in the Water, which would have made the Bulk of his Arm greater, according to the Chain Hypothesis; but instead of the Water's rising, it rather sunk: and without a visible Swell of the whole Arm, I fear the Supposition of the Chain of Bladders will gain little Ground. Of all the Accounts concerning muscular Motion, I must own what Dr. *Browne Langrish* wrote upon that Subject is most satisfactory to me.

EXPERIMENT 2. *Plate* 24. *Fig*. 8.

E G B is a strong Glass Receiver with a Brass Hoop cemented on at its Bottom B, (whose Opening there is big enough to let in the Brass Hemispheres) and another cemented on at top at G. In a Frame of Wood, between two Pillars, (such as you see in *Fig*. 12.) a Plate and wet Leather being laid on the bottom Board, any Body to compress the Air upon, suppose here F a blown Bladder, is put into the Glass, then a wet Leather upon it; next the Brass cylindrick Dish of *Fig*. 10. with the Ring of Wood W R to put over the Collar H into the Dish, so that being prominent above the Brass, the cross Piece of Wood E F (*Fig*. 12.) screw'd down by the Nuts of the Pillars, may press all tight together, without damaging the Brass Dish, which holds some Water to keep the Leathers about H moist. Screw a Cock at H, and the End of the Syringe into

Lect. XI. that Cock, which being shut after the pumping in is over, will retain the condens'd Air.

Experiment 3.

Plate 24. Fig. 8. The Bladder E in the Glass G B being full blown, at every Injection of Air from the Syringe, the Bladder appears contracted, and shews how much the Air is condens'd: so that when the Bladder is half subsided, the Density of the Air is doubled, or one Atmosphere is injected, (as is express'd in Mr. *Haukshee*'s Book of Physico-mechanical Experiments) and if the Cock be then shut, and the Syringe taken off, the Bladder will remain flaccid, till by opening the Cock to let out the injected Air, the Bladder will rise again to its first Dimensions.

But this not being an exact way to know how much Air has been injected, there is a mercurial Gage O E *o c d* D, contriv'd to know the exact Density of the Air in the Glass at any time, and consequently its Quantity dependent upon it. This Gage is shewn large in Figure 9, and its Description is as follows.

D *d e f c* is a small Glass Tube open at D, but hermetically seal'd at the End *c*, of about one Tenth of an Inch in Diameter. D E is a larger Tube hermetically seal'd at D, where a certain Quantity of Mercury taking up about two or three Inches in length, receives and covers the open End of the smaller Tube, for the Purpose hereafter to be describ'd. The other End C of the great Tube is cemented strongly into the Brass Elbow-Piece O E *o* at C, so as not to be quite at right Angles with O *o*, but to incline a little downwards, that the Mercury at D may not run towards C, and go into the condensing Glass. This Gage is screw'd on to the Piece of the Brass Dish of *Fig.* 10. or at *o*, *Fig.* 8. and the injecting Syringe at O, a Cock being interpos'd at O, or *o*, or not used at all, according to the Nature of the Experiment to be made.

As the Air is injected into the condensing Glass, and the great Tube of the Gage at the same time, but not into the little Tube of the Gage, it must be rarer and weaker in that Tube; for which reason that Air will recede and allow some of the Mercury from D to go into the said Tube, and that in proportion as the Air is condens'd in G B. *d*, *e*, *f*, are three Rings of Springy Wire, to shew by the advancing of the Mercury in the small Tube, that the Density of the Air is doubled, tripled, or quadrupled; because the Air which filled all the little Tube, now takes up only the Space C *d*, C *e*, or C *f*; so that, in Mr. *Haukshee*'s Style, one, two, or three Atmospheres are forced in.

Expe-

EXPERIMENT 4.

TAKE such a square Bottle as is represented at *Fig.* 8. *Plate* 25. seal'd up with common Air in it, and put it into the condensing Glass inclos'd in its Cage; then having made the whole Machine tight, inject Air with the Syringe till you break the square Bottle; and observing the Mercury in the Gage, you will, by the Place of the Mercury in the little Tube, know exactly the Density of the Air whose Pressure broke the Bottle. Plate 24. Fig. 8.

EXPERIMENT 5.

TAKE a thin round Bottle, of about the Size of the square Bottles that are broken upon the Air-Pump, and about the same Thickness, and upon trial you will find that its Parts will so support one another, that the external Air will not be able to break it, when you have drawn out all its internal Air by the Pump: Now if you put this in the condensing Glass, you may perhaps break it by condensing Air upon it; but if it does not break when the Mercury is come up to *c* in the Gage (that is, when two Atmospheres are injected) venture no farther, lest you should break the condensing Glass. Then the Bottle sustains 24 Pounds upon a round Inch; whereas when the Air was exhausted from it, the external Air compress'd it only with the Pressure of 12 Pounds upon every round Inch.

GENERALLY, one of these condensing Glasses will bear a triple Density of Air, or two Atmospheres to be injected, but the reason why it is not safe to venture farther is, because the Pressure being made outwards, the Parts of the Glass do not support one another like an Arch, which they do against an external Pressure; for what wou'd sustain 10 Atmospheres, pressing from without, would hardly resist 3 or 4 of them acting from within. When a Glass is very strong, there is a way to try how far it may be trusted, which is this: Take a Board of Oak about an Inch thick, and 18 Inches square; in which having cut a Passage quite to the Middle to take in the lower Part of the Gage at *o*, slip it on over the condensing Glass between *o* and C: then you may inject Air without fear, because if the condensing Glass should break, the Board will save you from the Pieces that may fly about, whilst at the same time you may view the Gage with safety, to know how many Atmospheres the Glass will bear: and if the Glass does not break, mark the Gage, that you may be sure not to let the Quicksilver in the Gage run beyond that Mark, or come quite to it in any Experiment, which you would make with safety.

Lect. XI. Plate 24. Fig. 11.

Sometimes there are Experiments to be made, in which the Gage O E *o* D wou'd be in the way; and then another Gage to be put within the condensing Glass, at its Bottom, must be made use of. It is represented in the 11th Figure. It is a short Cylinder of Wood, like that of W R, *Fig.* 10. about an Inch thick, with an Hole thro' its Middle between *a* and *b*, of about $1\frac{1}{2}$ Inch Diameter: the outward Diameter of the Cylinder must be of about 4 Inches, or such that the Cylinder may easily stand within the condensing Glass on the Plate, supporting its Bottom at B. There is an Hole at A of about $\frac{3}{4}$ of an Inch Diameter, and $\frac{3}{4}$ of an Inch deep, to be fill'd with Mercury. *a c d b* is a small Glass Tube, open at *a*, but hermetically seal'd at *b*, and bent to a right Angle at *c*, the Middle of the Distance between *a* and *b*. It is plain that if the open End *a* of this Tube be immersed in Mercury, and then the Air on the Surface of the Mercury be condens'd, the Air in the Tube will recede towards the Elbow *c*, and the Mercury shew how far it is condens'd by following it. If the Mercury goes to *c*, then one additional Atmosphere bears upon its Surface, and two Atmospheres if it is come to *d*; which Places are mark'd by Rings of springing Brass-Wire. At *a* and *b*, about an Inch of the Ends of the Tube are bent to a right Angle, that the End *b* may go into the Wood, whilst the End *a* goes under the Surface of the Mercury, where it is held by a Cork to keep its Opening under the Surface of the Mercury, whilst Air is injecting into the condensing Glass, that no shake may disturb the Gage, which must be within the Glass at bottom, that you may by looking thro' the Glass see how much Air you have injected; as for Example, one Atmosphere if the Mercury is at the Elbow at *c*, and two Atmospheres if it be come to *d*. *N. B.* This Tube which is in its Place at *Fig.* 11. is represented separately at A, and mark'd with the same Letters as on the Wood.

Experiment 6. *Plate* 24. *Fig.* 12.

Upon the Brass Plate *g* of the Frame P P E F *s* design'd to hold the condensing Glass, put on first a wet Leather or two, then the Gage of *Fig.* 11. then screw in the Plate thro' the Hole in the Middle of the Gage Cylinder, one of the Brass Hemispheres used in the 22d Experiment of the Air-Pump, by means of its supporting Piece *b c*: then having laid on a wet Leather over that Hemisphere *b*, put on the other Hemisphere *a*, and press it down close that no Air may come in between the Hemispheres. Cover the whole with the condensing Glass P P, and screw down upon it the Cross-piece E F, which holds down the Brass-Dish of *Fig.* 10. with the Pressing-piece W R of *Fig.* 10. and keeps all tight to the Glass by the Interposition of wet Leathers. Slip down thro' the Hole H of

of the Collar of Leathers, a thick Iron Wire or Rod reaching down to the upper Hemisphere *a*, and screwing into it. Then screw your Cock and Syringe to the upper End of the Wire above mention'd, which is so perforated, that the injected Air coming down thro' it goes into the condensing Glass without passing into the Hemispheres, which are press'd together with common Air between them. Observe by the Mercury of the Gage at the Bottom within the condensing Glass, thro' which you see it, when you have doubled the Density of the Air, or injected one Atmosphere. Then you will find by the Steel-yard hanging at some fix'd Point over the condensing Frame (which must be screw'd fast to the Floor) that it requires about 140 Pounds to draw them asunder. This compar'd with the Experiment 22. on the Air-Pump, shewn in *Plate* 25. *Fig.* 28. shews that Air of double Density is just as much stronger, by its Pressure, than common Air, as common Air is than a *Vacuum*: and this Pressure when the Barometer stands at 30 Inches, is in round Numbers equal to 12 Pounds upon a round Inch. N. B. *As the Air varies in its Pressure, the Weight requir'd to separate the Hemispheres in this Experiment, or the 22d of the Air-Pump, is from* 140 *to* 150 *Pounds.* Lect. XI.

Experiment 7.

Exhaust the Hemispheres at the Air-Pump, before you put them into the condensing Glass; and having injected one Atmosphere, you will find it require 280 *lb.* to draw them asunder.

Experiment 8.

Upon the same Hemispheres exhausted before they are put into the condensing Glass, inject two Atmospheres, and it will require 420 Pounds to draw them asunder. *N. B.* The Collars of oil'd Leathers in the Brass-Dish at top of the condensing Glass, with the Water in the Dish, hold all so tight, that no external Air is admitted in separating the Hemispheres: and two or three little Collars of Lead are on the slip Wire, lest the rising Hemisphere should break the Glass by its great Jerk upon the Separation.

Experiment 9. *Plate* 24. *Fig.* 13.

This Machine, call'd the Brass-Condenser, consists of two very strong Brass Cups, whose Brims are press'd together with a wet Leather between; and they are held by an Iron Cross-bar kept down with Iron Pillars and Screws, so as to sustain an immense Force. Here the outside Gage represented at *Fig.* 8, and 9. is to be made use of: and either Air or Water may be injected. Bottles that cou'd not be broken upon the Air-Pump, by the Pressure of the external Air, nor even by 2 or 3 Atmospheres

in

Lect. XI. in the condensing Glass, (not even when exhausted before) because of their Roundness, will be broken soon: provided the Bore of your injecting Syringe is not too big; for the less the Diameter of the forcing Piston, the more the Force of Condensation you can apply.

THE Resistance of the Piston of the injecting Syringe arises from this Consideration. Since a Column of common Air, whose Base is a circular Inch, weighs about 12 Pounds; when the Density of the Air is double, the Resistance against the Piston of an injecting Syringe, whose Area is an Inch, must be equal to a Weight of 12 Pounds: so that you must reckon 12 Pounds for every Degree of Density of the resisting Air, and multiply it by the Area of the Piston. For Example, if the Air is condens'd by a Syringe of an Inch Diameter, when it is condens'd 10 times, the Hand pushing the Piston feels the Weight of 120 Pounds; whereas if the Syringe had been but of half an Inch Diameter, he would have only felt a Resistance of 30 Pounds; or not the Resistance of 120, till the Air had been condens'd 40 times. With a Syringe of a large Diameter, the Air will be injected sooner; but more forcibly, by one of a smaller Diameter: so that if you want a great deal of Air to be injected, begin with a large Syringe till the Resistance is too great; then go on with a small one.

EXPERIMENT 10. *Fig.* 13.

Plate 24. Fig. 13. TAKE the little Bell of the 33d Experiment of the Air-Pump, and shut it up in the Brass Condenser; then you will hear it but at a small distance. Inject one Atmosphere, and you will hear it as far again. Inject two Atmospheres, and you will hear at a distance proportionably greater, and so on.

IN Wind-Guns, where it is requir'd to have the Air strongly condens'd, Syringes of a small Bore are made use of, very little more than half an Inch in Diameter, and fix'd in the Stock of the Gun. I have taken a Draught and slight Explanation of one of those Machines from Mr. Professor *Muschenbroek*, in his *Essays de Physique*, Vol. II.

Plate 24. *Fig.* 14.

THIS Gun is made of Brass, and has two Barrels. The inside Barrel KA of a small Bore, from which the Bullets are shot; and a larger Barrel on the outside of it ESCDR. There is a Syringe SMNP fix'd behind the Barrels in the Stock of the Gun, whose Rod M draws out to take in Air; then it is push'd in in the Direction MN, where the Piston SN drives the Air before it thro' the Valve EP in the Cavity between the two Barrels, where it is retained between the said Valves. The

Ball

Ball K is put down into its Place, in the small Barrel with the Rammer, as in another Gun. There is another Valve at S L, which being open'd by the Trigger O permits the Air to come behind the Bullet, so as to drive it out with great Force. If this Valve be open'd and shut suddenly, one Charge of Air may make several Discharges; because only part of the injected Air will go out at a time, and a new Bullet may be put into the Place K: or the whole Air may be discharged at once, which will shoot more forcibly. This is done by means of the Lock of *Fig.* 15. when fix'd to the Gun in the Place usual for other Guns. For the Trigger being pull'd, the Cock will go down and drive a Leaver that opens the Valve. This is a Description of the old Wind-Gun; but an ingenious Workman call'd *L. Colbe*, has very much improv'd it, by making it a Magazine Wind-Gun; so that 10 Bullets are so lodg'd in a Cavity near the Place of Discharge, that they may be drawn into the shooting Barrel, and successively shot so fast as to be of the same use as the same Number of Guns; the only Motion requir'd (when the Air has been injected before-hand) being the shutting and opening the Hammer, and cocking and pulling the Trigger. But the 16th Figure represents the present Form of Mr. *Colbe*'s Gun, with its Improvements, as big as every Part is in the Gun itself; so much being shewn here, as makes the Excellency of the Magazine-Gun, as he calls it; the rest being like another Wind-Gun. We are to suppose a vertical Section along the Axis of the Gun, and it will appear as follows. E E is part of the Stock. G is the End of the injecting Syringe having a Valve, and opening into the Cavity F F F F, which is the Space to contain the Air between the two Barrels. K K is the small or shooting Barrel, which receives the Bullets one at a time from the Magazine, being a serpentine Cavity, wherein the Bullets *b*, *b*, *b*, *b*, &c. nine or ten, are lodged; and from whence by one Motion of the Hammer (which we shall describe) they are brought into the Barrel to I, from whence they are shot out by the Opening of the Valve V, which lets in the Air from the Cavity F F F in the Channel V K I, and so along K K K the inner Barrel, whence the Bullet is discharged. *s* I *s* *i* M *k* is the Key of a Cock, having an Hole thro' it; which Hole in the present Situation makes part of the Barrel K K, being just of the same Bore: so that the Air which is let in at every Opening of the Valve V, comes behind this Cock, and taking the Ball out of it, carries it forward, and so out of the Mouth of the Piece. To bring in another Bullet to succeed I (which is done in an instant) bring the cylindrick Cavity of the Key of the Cock, which before made part of the Barrel K K K into the Situation *i k*, so that the Part I may be at K, and holding the Gun upon your Shoulder, with the Barrel downwards and

Lect. XI.

Plate 24. Fig. 14, 15, 16, &c.

Lect. XI. and the Magazine upwards, one Bullet next to the Cock will fall into it out of the Magazine, but go no farther into this cylindrick Cavity than the two little Pieces *s, s*, like Finger Ends, with tender Springs behind them will let it; by which means only one Bullet at a time will be taken in, and the Key with the Bullet being return'd to its former Place will bring the Bullet to I, to be discharg'd at the next Opening of the Valve, leaving the rest of the Bullets in the Magazine. The two Circles 2, 2, 2, represent the Cock-Barrel wherein the Key above-mention'd turns about on an Axis not represented here, but visible in *Fig.* 17. This Axis is a square Piece of Steel, on which comes the square Hole of the Hammer H; by which (when it is brought down to shut the Pan of the Gun) the cylindrick Cavity mention'd is brought to open to the Magazine, from which it receives a Ball at I, when the Magazine *b b*, &c. is held upwards. Then opening the Hammer, as in *Fig.* 18. the Bullet is brought into its proper Place near the discharging Valve, and the cylindrick Cavity of the Key of the Cock does again make part of the inward Barrel KKK. N.B. *Fig.* 17, and 18. *are half as big as the Pieces which they represent.*

Plate 24. Fig. 17, 18.

WE come now to consider the Make of the Valve, and the Manner of opening it to discharge the Gun. A Piece of Brass whose Bottom is a truncated Cone is made to fit the Hole LV, which that it may do the better, prepar'd Leather is tied round this Valve, whose upper Part has a Shank passing thro', and made fast by a Nut to the End N of a very long Brass Spring of about 18 Inches N N, whose fixed Point or Center of Motion is between the two Barrels, or rather on the Outside of the inner Barrel in a Strap under which its small End is fix'd, whilst its great End pressing in the Direction VP keeps the Valve V shut; and when the Valve has been open by pushing up the Pin *p* P, brings it again to its Place, where it holds it tight. Besides the Force of this Spring, the injected Air contained in the Cavity F, F, F, between the two Bands presses and keeps down the Valve with great Force. In order to raise the Valve upon occasion (as when you would shoot) there is a Brass Pin P*p* about an Inch and an half in Length, and $\frac{1}{10}$ of an Inch in Diameter, which push'd up thro' the Hole OO, just big enough to let the Pin move up and down without any sensible Loss of any of that condens'd Air that descends into the small Barrel behind the Bullet, when the Valve has been lifted up by the Push of the Pin upwards, which is but instantaneous, unless when the whole Air is discharged at once to give the Bullet the greatest possible Velocity.

THE Cock and Plate of the Lock being taken off, the principal Parts of the Lock for pushing up the Pin *p* P to make a Discharge come in

 view,

view, ſuch as Q, R, T, S, W, &c. which we ſhall deſcribe one after another. Lect. XI.

Q is an horizontal Leaver moveable round a Center Pin *n*, whoſe upper Side at *l* is flat, for the End of the diſcharging Pin P*p* to reſt upon; whilſt its under Part is bearing upon the End *m* of the tumbling Leaver R, which puſhes it up together with the Pin at every Fall of the Cock. Plate 24. Fig. 16.

T is the Tumbler moveable by, and moving, the Cock, which we ſuppoſe faſten'd to it at T. This Tumbler is driven by the main Spring W W lifting it up at one End W, whilſt its other End *u* puſhes down one End *v* of the tumbling Leaver R, whilſt the other End *m* riſes, and in its Riſe lifts up the firſt horizontal Leaver with the Pin to open the Valve V and make a Shot.

y x is the Seer, Detent or Trigger-Piece which is moveable round a Center Pin at *n*, and by its Point *x* bears againſt the Half-cock Notch of the Tumbler at 5, and the Full-cock Notch at *x*; from whence it is occaſionally unlocked by the End *z* of the Trigger Z*z* moveable about its Center Pin, &c.

Upon the Pull of the Trigger, the End of the Seer or Trigger-piece looſed from its Notch goes under *x*, and gives the Spring W W full power to act upwards, and move the Tumbler in the Direction W T *uv* 32. The Tumbler by its End *u* deſcribes the Arc *u v* 32 carrying along with it the End *v* of the tumbling Leaver R, whoſe other End *m* deſcribing the Arc *m l q*, raiſes the flat End *l* of the horizontal Leaver Q up to *q*, where lifting up the Pin P*p*, it opens the Valve V and diſcharges the Gun. But this Situation of the Pin P*p*, and Poſition of the Leaver Q*q* is only inſtantaneous; becauſe the End *u* of the Tumbler parts with the End *v* of the tumbling Leaver at 3, going it ſelf to 2, whilſt *v* goes to 1, and *m* coming from *l* lets the horizontal Leaver come back to its old Place *v m*, which it does by the Reaction of the Spring *m t* and the condens'd Air in the Cavity F F F; and by that means only Part of the Air is let out at once; ſo that 10 or 11 very effectual Shot may be made one after another, without new Injection of Air.

If the End *u* of the Tumbler had gone no farther than 3 (which is ſometimes done by ſlipping a little Piece of Steel under the Notch in the Middle of the Cock) it wou'd have kept down under it the End *v* of the tumbling Leaver, whoſe other End remaining at *l*, would have kept the horizontal Leaver and the Pin upon it up in ſuch a manner that the Valve V would have continued open, and all the injected Air would have been diſcharg'd at once.

There are Springs belonging to ſeveral Pieces of the Lock not expreſs'd here, which ſerve to keep them in their Poſitions, or to reſtore them to

 them,

Lect. XI. them, when they have been struck out of them. 1*st*, The Hammer Spring which keeps the Hammer shut, as at *Fig*. 17. or open as at *Fig*. 18. 2*dly*, The Seer Spring to raise the Point of the Seer to its proper Notch in the Tumbler, as 5 or *x*. 3*dly*, A Spring pressing up between *m* and *n* to keep the horizontal Leaver from falling out of its Place. 4*thly*, A Spring pressing upon the tumbling Leaver R (between R and *m*) to restore it to its Place after it has been struck down. The last Spring, and which is drawn here and must be describ'd, is a little Spring *t* 2, *t*, fix'd to the under side of the tumbling Leaver R for the following Use. R is made of two Pieces; otherwise the End of the Tumbler *u* when once below it, wou'd not come above it again; but the End *u* having a Tongue which goes into a slit, moves round the Pin *w*, upwards so as to give passage to the End of the Tumbler when it rises from underneath; but it meets with a Stop at *w t*, when *v* is going down. When *v* is pass'd by, in going up, the little Spring above-mention'd by its End *t* presses on the Heel of the little Piece *v* to bring it down from *w u* into the first Situation *w v*, to receive the Pressure of the Tumbler.

Plate 24. Fig. 16.

The Magazine *k b*, *b*, *b*, *&c*. D, receives the Bullets at its Opening D, over which a Plate X comes to shut them in; and they are kept in readiness to be brought into the shooting Barrel by the Motion of the Hammer in the expeditious manner describ'd.

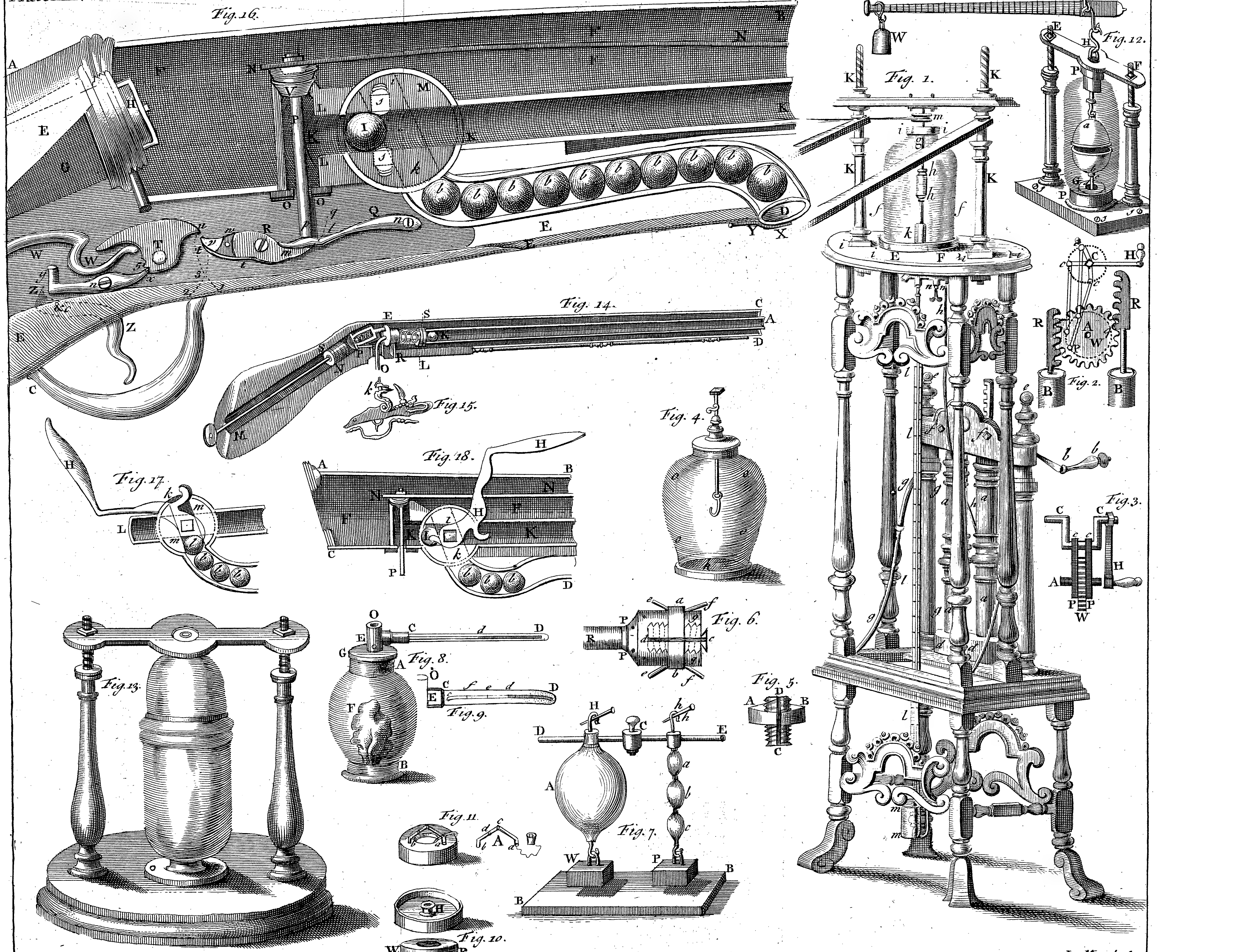
This is far preferable to any of the old Wind-Guns; because tho' some of them will hold Air for several Discharges, the Bullet must be put down the Mouth of the Barrel every time, which cannot be done soon; but in *Colbe*'s Gun the Bullet is brought into the Barrel in a Moment. Tho' the Pin P *p* with the Valve and long Spring N N is to be met with in some of the old Guns, as well as the Tumbler and some of the Leavers in the Lock, yet the Cock and the Magazine are entirely new, as also several Contrivances in the Lock; and the whole so well executed as not to be easily put out of order. For these Reasons it may be look'd upon as the best Defence against Highway-men, or Robbers that Travellers are aware of, because when they have cause to suspect them, they may make five or six Discharges before a Thief can come within Pistol-shot.

And now to make this Book, as well as the First Volume of my Course of Experimental Philosophy as compleat as I can; I will conclude with a Chapter or Lecture, shewing the Application of the Principles that we have explain'd, to the Uses of Life, in giving the Description of such Engines in present use as are the best in their kind, with Observations upon them: But first give by way of Notes to this Lecture some miscellaneous Observations upon Air, which could not so properly be put in the Lectures; and that without any Order.

Anno-

Plate XXIV.

front.^s p. 402.



J. Mynde sc.

Annotations upon the Eleventh Lecture.

WHEN Sir *Isaac Newton* publiſh'd the ſecond Edition of his Opticks, in the Year 1717, he added Queries to the 3d Book. Thoſe, together with the reſt of the Queries, contain an excellent Body of Philoſophy, and upon Examination appear to be true; tho' our incomparable Philoſopher's Modeſty made him propoſe thoſe things by way of Queries, which he had Obſervations enow to ſatisfy himſelf were true; he was unwilling to aſſert any thing that he could not prove by Mathematical Demonſtrations or Experiments. This made a great many People conſider what he ſays in them merely as Conjectures; and I know very few, beſides the Reverend and Learned Dr. *Stephen Hales* and my ſelf, that look upon them as we do on the reſt of his Works. Ever ſince that time I have made ſeveral Experiments, which have confirm'd my Belief of his Opinions, and Dr. *Hales* has made a great many more, which have clear'd up many of his Hints, and ſhew'd that Sir *Iſaac* had made no raſh Aſſertions. As it would be tedious to mention more Particulars, after I have ſaid ſo much on the Contents and Operations of the ſeveral Parts of our Atmoſphere, I refer my Reader to the Doctor's excellent Treatiſe of *Vegetable Staticks*; of which I have given my opinion in the Abſtract I made of it in the Year 1727, printed in the *Philoſophical Tranſactions*, N° 398, 399; and his Treatiſe of *Hæmaſticks* publiſh'd ſince: Both Books are made into one by Monſ. *Du Buffon*, who has tranſlated them into *French*, in ſuch a manner as to do no diſcredit to the Author.

I Shall only mention here ſome Things obſerv'd by the Doctor, and a few things which I take to be natural Conſequences of his and my Experiments concerning Air.

That Air is ſometimes in a fix'd, and ſometimes in an elaſtick State, (the laſt being the only State in which Philoſophers took it to be before Sir *Iſaac Newton*) as well as how it may be chang'd from one of thoſe States to the other, ſometimes with great Eaſe, and ſometimes with great Difficulty, has been ſhewn by Dr. *Hales*, by a vaſt Number of curious Experiments.

Animals and Plants are chiefly ſupported and increas'd by Air in theſe two States; the ſolid Parts by fix'd, and the fluid Parts by Elaſtick Air; for it enters the Pores of Plants and Animals in great plenty, where ſome of it becoming fix'd, is as it were the Cement which joins the ſolid Parts together, whilſt what remains elaſtick keeps up the Activity of the Fluids.

The elaſtick Air which is contain'd in many Bodies, is kept in them by the Weight of the Atmoſphere; and may be got out by common boiling and the Air-Pump, in the manner that we have ſhewn by many Experiments:

Annotat. Lect. XI. but the fix'd Air which is much the greater Quantity will not be got out but by Distillation, Fermentation, or Putrefaction.

If fix'd Air did not come out of Bodies with difficulty, and spend some time in extricating it self from the Substances in which it is contain'd; it would tear them to pieces. Trees wou'd be rent by the Change of Air from a fix'd into an elastick State; and Animals would be burst to Atoms by the Explosion of the Air in their Food. Dr. *Hales* found 48 Atmospheres in one Apple (that is, the Air condens'd 48 times;) so that its Pressure outwards was equal to 11776 ℔. and that of a cubick Inch of Oak of 19860 ℔. against its six Sides. So that if the Air was let loose at once in these Substances, they would tear to pieces every thing about them with an Explosion far superior to Gun-powder.

Yet in eating an Apple, if it ferments in a Man's Stomach, and parts with all its Air, this is done by degrees, the Air has time to go out; and perhaps other Parts of the Food absorb Air as fast as the Apple generates it. *N. B.* Dr. *Hales* has observ'd that the Digestion is best perform'd when our Food (generally made up of Variety of Things) generates Air a little faster than it is absorb'd.

In the Year 1708, I went thro' a Course of Experimental Philosophy with Dr. *John Keil*, at *Christ-Church* in *Oxford*, who, in his explaining to his Auditors the Use of the Lungs, said there was Air in the Thorax on the outside of the Lungs, which acted upon the Lungs in the manner that we have describ'd *; and gave me satisfactory Reasons for believing it: tho' some Persons opposed that Opinion, and gave Reasons to shew that the Lungs might play without any such Air included in the Thorax. I was afterwards farther confirm'd in the Opinion given by the Doctor, by the Relation of Circumstances of some Surgeons who had cur'd Wounds in the Thorax, and even in the Lungs; and also by some anatomical Operations I made for that purpose. Afterwards when I came to give Courses of Experimental Philosophy, it happen'd that at one of my Courses in *London*, I had several Physicians who had studied under Dr. *Boerhaave*, who at that time did not believe there was any Air in the Blood (tho' I think he alter'd his Opinion since) and I asserted that there was Air in the Thorax, and also in the Blood. The Gentlemen that were come from *Holland* gave their opinion to the contrary, especially the late Dr. *Alexander Stuart*, Physician to her late Majesty, who said he had several times open'd the Blood-Vessels of Animals *in vacuo*, and never found Air in them. Upon this I told him that certainly his Air-Pump must not have been tight; and we agreed to repeat the Experiment in my Pump, which I wou'd make very tight. Then we tied the jugular Vein of a living Calf very fast, with two Ligatures 3 Inches asunder, and so cut out that Piece of Vein an Inch on the outside of each Ligature. We fasten'd this Vessel over the Top of a Coffee-Cup, and a Lancet to the lower End of the slip Wire that came down into the Pump thro' a Collar of Leathers, that it might be push'd down to cut the Vein. When the Receiver was well exhausted, we push'd down the Lancet thro' the Blood-Vessel, and the Blood came down into the Cup full of Air and Froth, which convinced every body.

*L. 7. An. 12.

To

To give a full Account of what relates to the Lungs in respect of Air, it is this.

Besides the cooling of the Blood, which happens by means of the Air at every Inspiration; the Air not only oozes gradually out of the Lungs into the Thorax in a small quantity; but goes thro' the Vesicles and joins with the Blood it self, where some Part of it becomes fix'd and joins with the Globules, and the rest circulates with the Blood to the very Extremities, which we have Phænomena to prove.

I took the Lungs of a Rabbit, and having tied the Wind-Pipe to a Glass-Tube, and tied up the other Vessels that we cut off, I blow'd them up with very little Force, till they were full; but adding a little more Breath I found that the Air escap'd, tho' the Lungs did not seem wounded. To find the Force capable of opening those small Passages I took a recurve Tube, or inverted Syphon, having one Leg of about 9 Inches, and the other of about 12, which last I held in my Mouth, having put about 7 or 8 Inches of Mercury in the Bend of the Syphon; then having sunk the Rabbit's Lungs under Water by a Weight, and taking in my Mouth the End of the Glass-Tube fasten'd to the Wind-Pipe, and at the same time the long Leg of the Syphon which was out of the Jar where the Lungs were immersed; I blew till the Mercury seemed to me to be about two Inches higher in the short Leg than in the long Leg of the Syphon; and at that time the Air began to bubble up in little Streams thro' the Water. When I blew harder, I did not perceive any new Streams of Air-Bubbles; but only the Air came faster, as the Mercury rose near an Inch higher. This shews the Lungs to be pervious, without being wounded; but yet some Force to be requir'd, greater than what naturally acts in Inspiration and Expiration.

Dr. *Hales* has found the Air in the Lungs to be dilated about $\frac{1}{8}$ more than common Air by the Heat of the Lungs, and therefore the Air in the Thorax on their Outside must be in that state at a Medium: so that as the Cavity of the Thorax is contracted by the Fall of the Ribs and Rise of the Diaphragm, this Air becoming more dense must depress the Lungs, which causes Expiration. When the Ribs are raised, and the Diaphragm is let down to a Concavity, the Cavity of the Thorax being increas'd, its Air is weaken'd, and yields to the external Air, which blows up the Lungs and makes an Inspiration. Now if either the Expiration or Inspiration be stopped at the Nose and Mouth, whilst the abdominal Muscles are acting to perform those Operations, there will be sufficient force to have Air pass into the Thorax from the Lungs, or from the Thorax into the Lungs, so as to alter that included Air in Quantity or Quality as the healthful State of the Animal requires.

As for the Air mixing with the Blood, by passing thro' the Lungs, which Dr. *Hales* believes, but dares not positively affirm; (tho' he gives many Reasons for its probability; as for example, that of 48000 Inches of Air that we breathe in an Hour, one 13th Part or 3692 Inches lose their Elasticity, much more than can be owing to the Moisture of the Lungs, and that a great deal of fix'd Air is got out of the Crassamentum of the Blood;) besides the Sulphur which comes out of the Lungs in breathing, and renders the Air effœte when

Annotat. Lect. XI. when we breathe the same Air long, tho' no sulphureous Body, or its Effluvia, be near——I think one Phænomenon puts it out of all doubt, *viz.* that Men can live in Dr. *Halley*'s Diving-Bell at prodigious Depths under Water, and suffer no Inconveniency; for how could a Man used to bear on his Body a Pressure of 30,000 ℔. only, bear with the same facility a Pressure of 300,000 ℔. if he did not breathe an Air of such a Density as is capable of bearing all that Weight? and such Air must be carried by the Circulation of the Blood to all the Extremities; otherwise it would be sensibly felt. As a farther Proof of this, let us consider what Mr. *Triewald*'s *Diver* told him that happen'd to him, when by Accident he was lower'd in the Bell only a Fathom, or a little more, too suddenly, *viz.* that he bled at the Nose and Ears, and felt an intolerable Pressure. What could this be, but that the condens'd Air had not time to pass with the Circulation to every Part, in order to bear the new, sudden, additional Pressure of Air. *N. B.* It is no Objection, that the Air is ten times denser in the Diver's Bell, to its entering the Lungs, and going thro' the fine Passages that carry it into the Blood; because the Particles of Air cannot adhere to one another, and thereby grow bigger; they only require to pass with a little more Velocity. Thus in Hydrostaticks we find that a round Hole of an Inch Diameter will transmit but a Ton of Water in an Hour, when the Surface of the Water is but an Inch above the Center of the Hole; where a Hole of the same Bore in an Ajutage whose Jet rises 70 Feet, will afford 30 Tons an Hour, tho' we know there is no Compression in Water, a greater Velocity being sufficient for this Phænomenon.

When three or four Persons are in a Coach, and draw up the Glasses, the Glasses soon become cover'd with Dew, which in a great measure hinders their Transparency; but when once the Dew has been wiped off, there is no more gather'd upon the Glass, but it continues transparent. The Reason of this Phænomenon is, that in comparison to the moist Vapours that come from the Persons in the Coach, the Glass is cold, and condenses them, remaining cold longer than any other Part of the Coach, as we find in damp Weather that Marble will become wet by condensing the Moisture of the Air. Then by degrees the Glass partaking of the Warmth of the Persons in the Coach, is no longer able to condense the floating Vapours into Water. The Proof of this is plain, by letting down the Glass into its Place; because there it cools, and then being brought up, it again condenses the Vapour, and gathers a Dew; without which it would not condense the Vapour, tho' in many Hours travelling.

Tho' few Animals can bear a Vacuum, very tender Animals will bear condens'd Air. I have tried a Linnet, and several other Birds, which have born two Atmospheres, besides the common Air, (that is, Air of triple Density) without seeming to be affected with it: and a Rat, on whom I injected four Atmospheres, without disordering him, expir'd in half a Minute in a Vacuum. This I take to be for the same reason that Men can go down to great Depths in Dr. *Halley*'s Bell, *viz.* that the dense Air gets into all the Cavities of the Animal encompass'd with it, and is thereby able to bear all the additional Pressure from without, provided it be laid on gradually.

As

As a Syringe does not throw in Air faster than an Animal can breathe it in, we can make no Judgment of what would happen if an Animal was to receive the Pressure all at once; there should be tried an Experiment of that kind, which I have not tried yet, but will some time or other. It should be done thus. A large and very strong condensing Engine, able to hold nine or ten Atmospheres, (as one of *Papin*'s Digesters, for Example) should have as much Air injected into it as it is able to bear, with a Cock and Pipe coming from it: then a small Animal, as a Rat or Mouse, should be shut up in a strong small Vessel but just able to hold him, the Cover of which should have a Screw to join it to the large Condenser, when it is full of compress'd Air; then by suddenly making a Communication between the two Vessels, by opening the Cock, it will appear what Effect the Pressure of the dense Air will have on the Animal. But one may guess it, by what happen'd to Mr. *Triewald*'s Diver, when he was let down too fast in his Bell. See Page 219. Annotat. Lect. XI.

Animals will die in stagnant Air, as we have already hinted; and this happens when the Lungs cannot be blown up to the Dimensions requir'd for Breathing, which is either owing to the Diminution of the Quantity of the Air to which an Animal is confin'd, when it is too much absorb'd by the Effluvia mix'd with it, which destroy its Elasticity, and make Moleculæ that precipitate with it; or else are too big to enter into the Vesicles of the Lungs, especially when those Effluvia are mix'd with acid Spirits that contract the Lungs. For tho' neither the Action of Heat or Cold, nor the Use of Syringes and Pumps, or any other mechanical Instruments, can with any Force, or in any Time, destroy the Elasticity of what we have call'd permanent Air; yet Elasticity is no immutable or inseparable Property of Air: for there is a Power of Attraction far greater than the repulsive Force of the Air, when it is in its elastic State, lodg'd in many kinds of Effluvia, which can reduce it to a fix'd State; and that Power is so much the greater as those Effluvia are finer. Nay, the very same Body, as its Effluvia or small Particles are coarser or finer, either will not absorb (that is, overcome the Elasticity of) the Air, or absorb it languidly, or absorb it very copiously. See Dr. *Hales*'s *Veg. Stat.*

There seem to be but two Powers, or general Agents in Nature, which, according to different Circumstances, are concern'd in all the Phænomena and Changes in Nature; *viz.* Attraction (meaning the Attraction of Gravity, as well as that of Cohesion, *&c.*) and Repulsion. It seems not reasonable to admit Elasticity for a Principle, since it may be generated and destroy'd in Solids *, and likewise in Fluids, as appears by many Observations and Experiments †.

* L 6 Page 39, 40, *& seq.*

Qu. 1. That Water does not appear by any Experiment to be elastick, tho' we know it to be made up of Particles capable of great Elasticity: May it not be owing to the Action of the two counter-acting Powers above-mention'd exerting their Force at the same time?

Qu. 2. May there not be Limits, beyond which the Attraction of Cohesion cannot bring the Parts of Water into, on account of that strong Repulsion taking

† See Dr. *Hales*'s Vegetable Staticks, Vol. 1. from Page 156, to Page 315.

Annotat. Lect. XI. taking place, which has always hinder'd it from being compress'd; tho' it is well known from Phænomena, that there are no Interstices wanting for the Parts of Water to come nearer together, were it not for that Power of Repulsion.

Qu. 3. May it not be owing to the want of Contact, or to the Smallness of its Degree, that Water, and those Fluids that have Water for their Basis, are so easily separated into elastic Vapours?

Qu. 4. May it not be owing to the same reason, that Spirit of Wine boils sooner than Water; since its rising to a less Height in capillary Tubes, shews that it has less Contact than Water?

Qu. 5. May not the Attraction of Cohesion exert a greater Force on the densest small Particles, so that Effluvia consisting of Parts of the greatest specifick Gravity (except the Attraction between sulphureous Bodies and Light) shall be able to overcome a greater Repulsion than that which makes Water incompressible, and keeps it to a fluid State.

Qu. 6. Is not the Attraction of Cohesion in solid Bodies almost insensible till they come into Contact, or very near Contact; and then extremely strong? Since we can bring no Metals to cohere by pressing them together, but Lead; and scarce any other Bodies, but some precious Stones? And only when they are very smooth and well polish'd?

Qu. 7. Is it not that kind of Attraction which exerts itself when Air is brought from an elastick into a fix'd State?

Qu. 8. Is not this Attraction far greater than what acted upon Water, when it acts upon Air? Since Air has been made denser than Water, and still retain'd its Elasticity and repellent Force; and it must be still more dense than that before it comes to a fix'd State *.

* Page 247.

Qu. 9. Does not the repulsive Quality of the Air act with more Force to drive the Particles from each other when separated; in proportion as it holds them together when fix'd?

Qu. 10. Is it not prov'd, that both the Attraction and Repulsion act much more strongly when they act upon Air, than upon Water and Vapour?

N. B. Tho' this may seem at first contrary to Phænomena, yet Observations rightly made will confirm it. The same Heat indeed which makes Water boil, rarefies it into Steam, which is 14000 times less dense than when it was Water, and 16 times rarer than Water at the Surface of the Earth, whilst the same degree of Heat rarefies Air but $\frac{1}{3}$. But to make the Comparison just, we are not to compare the Effect of Heat to rarefy the Air, when it is already in an elastick State, with the Effect of the same acting on Water to turn it into Steam; but we are to compare together the Difference of Density of Water, when cold, from the Density of the Vapour rais'd from it, with the Difference of the Density of the Air, when in a fix'd State, to the Density of the same, when become elastick; and then we shall find a much greater Difference between fix'd and elastick Air, than between Water and Vapour, when it is most expanded. In Dr. *Hales*'s Distillation of the *Calculus humanus*, half of which was fix'd Air; that Air was expanded 1290 times as it came into an elastick State, and of the Density of the Air we commonly breathe; which is

is but the 1000th Part of the Expansion of the Air in the Air-Pump, when the Pressure of the incumbent Atmosphere is taken from it: and at great Heights the Rarity of the Air exceeds that much, and we know no Bounds to its Expansion. At the Height of 10 Miles above the Earth's Surface the Air is much rarer than any degree of Steam. Nay, and the Steam itself, as it floats in the Air, does not keep the Rarity with which it first rose from the Surface of the boiling Water; but is condens'd 10, 12, or 14 times, in order to form those Clouds which rest in the Air at an Height of two Miles, one Mile, or half a Mile; there being seldom any Clouds higher than two Miles. But if the Steam made Clouds when it is 16 times rarer than Air, those Clouds would have their *Æquilibrium* at the Height of 7 $\frac{1}{2}$ Miles, where the Air is 16 times rarer than at the Earth's Surface. See Sir *Isaac Newton*'s Opticks.

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Qu. 11. May not different sorts of Air be produc'd by Distillation, and Fermentation, and Putrefaction, not only from different Bodies, but even from the same Body: and may not that Air be permanent, which is extricated and shaken off from the most solid Parts, whilst that which is produc'd from the more aqueous Parts is often re-absorb'd by the solid Body, or some of its other Effluvia?

Qu. 12. Does not it appear that both animal and vegetable Substances contain different sorts of Air: since the *Calculus humanus*, and the Rhenish Wine Tartar, which in Dr. *Hales*'s Experiments generated the moist Air, absorb'd again $\frac{1}{3}$ Part of it in eight Days; but the Air that was left was permanent, and therefore very different from the other.

Qu. 13. Do not mineral Bodies also produce, or generate different sorts of Air; of which, when some is re-absorb'd, the rest continues permanent?

Qu. 14. When the Air changes from an elastick into a fix'd State, what becomes of that prodigious repulsive Power in the Air that no mechanical Force could surmount? Is it not overcome by a stronger Power of Attraction in Contact; but yet so as to remain still in the Body, tho' inactive? And may it not be call'd a latent Power of Repulsion?

Qu. 15. When acid Particles, that are extremely active, rush against hard Bodies to separate their Parts, and beat them off into elastick Air, causing a Heat and Fermentation, does not this latent repulsive Force help that Sollicitation; and by degrees recover its Force?

Qu. 16. Does it not appear from what we have said in our Dissertation concerning Electricity; and in the next Dissertation concerning the Rise of Vapours, that Air is electrical: and that Vapours would precipitate into Water upon the Removal of the Heat which expanded the Water into Vapours, (as it happens in the Engine to raise Water by Fire;) if it was not for the Electricity which Air communicates to the Vapours, whereby they repel one another, and settle into Clouds; having by that means a limited repulsive Force, whereby they do not change their specifick Gravity, but their Place, as the ambient Air changes its Density. For if the repulsive Force of the Vapours could be increas'd or diminish'd upon the Removal or Increase of the ambient Pressure, we never should have any Rain.

Annotat. Lect. XI. *Qu.* 17. Does it not shew great Wisdom and Goodness in the supreme Being; that the Attraction of Cohesion acts upon Water and aqueous Fluids differently from what it does upon Solids, and such Fluids as are compos'd of Exhalations, or the Effluvia of solid Bodies? *viz.* to facilitate the Evaporation of Moisture from humid Bodies and watery Fluids; and to help the Formation of Rain from those Vapours and Steams of which Clouds are made?

For when this Attraction has brought watery Particles into Contact, or rather very near it, does it not cease to bring them any nearer, either by losing its farther Activity, or being check'd by some insuperable repulsive Force, which prevents the farther Condensation of the Liquor. When perhaps in regard to all kinds of Air and Exhalations generated from solid Bodies, the Attraction of Cohesion begins * but at a nearer Contact than that at which it ended, in regard to Water: because of the Necessity there is for Water to be thrown into Vapour, and rais'd up by a small Degree of Heat separating its Parts by intestine Motion, or carried off by the Electricity of Particles that attract it; both for forming Clouds, and drying moist Bodies upon occasion. Whereas it is necessary that solid Bodies should not have their Parts so easily separated. Again, the reason that the Attraction of Cohesion, in respect of Water or watery Vapours, begins to act at a sensible Distance, sometimes more than a quarter of an Inch, is, that when those watery Vapours that float together, (yet repelling one another by an Electricity they have receiv'd, or by the Heat which first rais'd them) come to have their Particles brought nearer together, (either by the Resistance of the Air when they fall in it by an accelerated Motion, by a Shock from a Flash of Lightning, or by running against the Side of a Mountain, or a Ridge of Hills) they may be brought together to form Drops of Rain; the Attraction of Cohesion prevailing here at a considerable Distance, a quarter of an Inch, or half a quarter, being a great distance, when compar'd with that at which the Attraction of Cohesion prevails, in regard to the Air, which must continue fluid much higher: and the sulphureous Effluvia, and other Exhalations, which are necessary to mix with the Air, even to great Heights, to purify it from noxious Steams, by Fermentations, and often by Explosions; and such Winds as are generated by the sudden Presence or Absence of hot Effluvia. Those that would be inform'd concerning Dews and Meteors, I would recommend to that accurate and indefatigable Philosopher *Petrus Van Muschenbroek*, Professor of Mathematicks and Experimental Philosophy of *Leyden*. See his Physical Essays already quoted, especially what he says of Dew, on which he has try'd many Experiments: see from Page 753 to 785 of the second Volume of his *Essays de Physique* above-mention'd.

There is a Phænomenon, which has lately happen'd; but as it is a Case in Physick I thought not to mention it. But as it relates to the Lungs, &c. *I have been desir'd by some Friends to insert it, as it is a Philosophical Consideration.* It is this: Ever since I can remember, the burning of a Brimstone Match to light a Candle has always given me a grateful Sensation: likewise

* By Dr. *Hales*'s Experiment, Air has been made denser than Water, without losing its Elasticity.

likewiſe the Smell of fir'd Gunpowder has been very agreeable to me; tho' both theſe are very unpleaſant to many People. I take the Cauſe to be this, *viz.* that the Veſicles of my Lungs are either larger, or have larger Paſſages into them, than the Veſicles of the Lungs of thoſe who cannot bear theſe Smells, and that *Moleculæ* made up of ſulphureous and aerial Particles are not ſo big as to be excluded from the Veſicles of my Lungs, where they remain till ſome Part of them join with the Blood, and the reſt goes off in Expiration. Of late being troubled with an Aſthmatick Diſorder, after a very ſevere Cold, I have found the burning of a Brimſtone Match painful, and very offenſive to me, tho' fir'd at five or ſix Yards Diſtance. I fear'd that there was ſome great Change in my Lungs, which occaſion'd this Alteration; but Dr. *Thomas Thompſon* (Phyſician to his Royal Highneſs the Prince of *Wales*'s Houſhold) told me that my Lungs were not impair'd, but that a ſtiff and glewy Mucus lin'd the *Bronchiæ*, or Veſſels of the Lungs, ſtopping ſome of the Paſſages into the Veſicles, and contracting others, (juſt as Mucus in the Guts ſometimes ſtops the Mouths of the lacteal Veſſels;) and that by removing this Mucus, he would ſet my Lungs clear of this Uneaſineſs. Accordingly, by taking his Medicines, I find myſelf entirely reliev'd of the Aſthma; and (what I mention this chiefly for) the Smell of burning Brimſtone gives me the ſame agreeable Senſation now, that it has been uſed to give me all my Life.

LECTURE XII.

On Engines, especially Hydrostatical and Hydraulick Machines.

Section I. I HAVE said so much in my first Volume concerning the Nature and Usefulness of mechanical Engines, the mechanical Organs or simple Machines, out of which all compounded ones are made up; and shew'd the Impossibility of a perpetual Motion, therefore the Folly of seeking for it; that I must desire my Reader before he goes on with this Lecture, to look back into the first Volume and read with care the 6th Annotation to Lecture 2d, all the 3d Lecture, and the 1st and 14th Annotation to the 3d Lecture. By that means he will have fresh in his mind, what ought to have been repeated here, but that I was unwilling to be guilty of Tautology. I will now only add a few Cautions for those who have occasion to make use of Machines: But first we must consider, that

1. THERE are certain Limits in the Application of Machines, which can never be exceeded: and it is the want of knowing this, which makes People so fond of new Inventions, in hopes of great Performances; when *the Effect of the best Engine does not exceed that of the worst one Part in five.* But here I must explain my self, and let my Reader know, that I suppose that what I call the *worst Engine*, has its Materials as good, its Parts as compleat, and its Work as well executed, as what I call the *best*; so named only upon account of the different Contrivance. That is, if a certain Power raises a certain Weight in a certain time, by means of a very plain and simple Machine; it is not in Art to contrive another Machine, whereby the same Power shall raise one fifth more of Weight in the same time; or the same Weight in a time shorter, by one fifth. This will seem a Paradox to those who are not acquainted with mechanical Principles; because we daily see the same Number of Men or of Horses, or the same Stream of Water perform ten times more with one Machine than with another; but this has not been on account of the Goodness of the *best*, but the Badness of the *worst* of the two Machines.

Power

Power lost, or misapplied, bad Materials, unnecessary Frictions, oblique Tractions where they should have been perpendicular, Animals working in disadvantageous Postures; Streams of Water half lost, Back-Water returning; whole Machines ill put together, *&c.* have been the Cause of these Differences. There is a great deal of room for ignorant enterprising People to exceed one another in mechanical Defects: There is a *Profund* among those that hammer, turn and file Wood and Metals, as well as among those that make Verses; and there are Plagiaries among Engine-Makers, as well as among Writers, and who as often make a wrong use of what they steal. An undertaking Plumber had once made a Water-Engine with a double Axis *in Peritrochio*, with two Barrels to raise Water to a Gentleman's House only about 30 Foot high; and having seen a Fly used in another Engine where it render'd an uniform Motion regular, thought it gain'd Force, and applied a very large one to the slowest Mover of his Engine, instead of applying it to the swiftest. When the Gentleman shew'd me his new Machine, where four Men work'd hard to raise the Water to his House; I took off the Fly, and then one Man work'd the Engine with more Ease than the four did when the Fly was on. Sometimes thro' Ignorance some Men finding an Effect ill performed by a very defective Machine, find out another way of doing the same thing, and fancy they have found out a Contrivance as many times better as the Performance happens to be better; whereas if the old Engine had been well executed, it would have differ'd but very little from the new. One time a certain Man wanted a Patent for what he call'd a new Discovery, (but the Invention was neither new nor his own) which he shew'd to a Gentleman, by whose Interest he hoped to get his Patent. The Gentleman told me, that a Person had shewn him such an Improvement in Wheel-Carriages, as to exceed 20 or 30 times what was common. As I knew the thing to be impossible, and was told the Person would not let me see it; I employ'd a skilful Friend to take a view of it, who told me that the Model to represent the common Carriages with which he compared his Machine was purposely made ill, 7 or 8 times worse than a fair Model, with the Wheels and Axle-Trees irregular: so that tho' his Engine did indeed exceed by many times what he call'd the common Carriages; yet the whole was a Cheat, the Advantage very small, if any; and the Event answer'd accordingly at last. So have I known some knavish Workmen, by some conceal'd Trick, pretend they had found out a perpetual Motion: or, which is the same, such Propositions as a perpetual Motion would be the consequence of, in order to get Money of credulous Persons. There was one not long since who left a good Trade to run after mechanical Projects, that shew'd a Model by

which

Lect. XII. which he made Persons of indifferent Skill believe, that one Pound descending one Foot would raise a Pound and a Quarter to the same Height, or by its Descent of a Foot would raise one Pound to more than that Height.

In civil and military Architecture, and such Works as Water is not concern'd in, there are made the fewest mechanical Blunders; or the Faults made, are easily corrected. Architects and Engineers are (or ought to be) skill'd in the Use of mechanical Organs: and as in few of their Operations they are confin'd to Time, or Space; they can increase the Effect of a Power at any time, by diminishing the comparative Velocity of the Weight; which can be done as they have almost at all times the Command of Time and Space. This was well understood by the Ancients, who made so much use of mechanical Instruments, that the Practice of Mechanicks was Part of the Art of War; for which no Expence was wanting: But the Invention of Gunpowder has so far chang'd the Manner of Fighting, that we have lost many fine Inventions, which were soon disused when they were no longer carried on at publick Expence. Hydraulicks indeed, which they knew but little of, and Mill-Work by Water or Wind, which they knew nothing of *, have been carried on by private Men, because of the Profit to be reaped from them; but there are more Qualifications requir'd for Water-Works than People commonly imagine; and yet there are perhaps more Quacks in this Art than any other except one. He that would meddle with Water-Works, should know so much of Mathematicks, as to understand mechanical Principles; be so much a Philosopher, as to be skill'd in Hydrostaticks and Pneumaticks; and be so good a practical Mechanick, as to know the Nature of Materials, and how to put them together in the best manner. Such were the Undertakers of Water-Works till the last Age.

There have indeed been some of a strong natural Genius for Mechanicks, that without any previous Knowledge of Mathematicks and Philosophy, have performed great Works, and built such Rules upon Facts and Observation as have stood them in good stead. By using themselves to think of one thing only at a time, they have learn'd many Properties and Proportions of Bodies, which comparing afterwards with great Attention they have been supplied with natural Mathematicks of their own. Such were *Hadley* and *Sorocold* the only Engine-Makers of any note of the last Age in *England*; who never fail'd of Success in their Undertakings, because their chief view was what the Works might be brought to perform, before they consider'd what Profit they should get by

* Men and other Animals were employ'd for grinding Corn till the sixth Century, when Water first was applied to Corn-Mills; and Wind not till about the Year 1200.

by them. Now we are over run with Engineers, (not *Ingenieurs* of a proper Education for the Science) and Projectors, especially in Water-Works; who only considering what they shall get by a Piece of Work, or what Advantage may be made of a cried-up Undertaking, perform things cursorily and in a slight manner to get Machines off of their hands, and sometimes draw in Numbers of People into ruinous and unpracticable Schemes. Few, like the late *Richard Newsham*, study the Advantage of the Buyers of their Engines. The Reader will judge of *Newsham*'s, by their Draughts and Descriptions at the End of this Lecture. Almost all the Plumbers and Mill-Wrights now set up for Engineers; tho' I hardly believe there are two of them who know how to measure the Quantity of Water requir'd to turn an Undershot, or an Overshot, or a Breast-Mill. They only judge of a Stream by the Eye, and he that has most practice is likely to succeed the best. Lect. XII.

SOMETIMES Mathematicians, who are more used to pure, than mixed Mathematicks, and not accustomed to mechanical Performances, have undertaken the Erection of a Water-Work, and have fail'd of Success, either thro' the Ignorance or Knavery of Workmen: for when a Mathematician, having considered in general his Design and calculated the Intensity of his Power and his Weight, leaves the Execution of the several Parts of the Machine to the Workmen, the Unskilful will undertake what he knows nothing of, and the Knave will disappoint his Master's Design by performing ill what he can declare *was not his own Scheme or Project*. There is a Combination among most Workmen to make a Mystery of their Arts: and they look upon him as a false Brother, who lets Gentlemen into their Manner of Working, and the Knowledge of the Price of all the Materials. Mathematicians and Philosophers they call *Men of Theory*, and have propagated a Notion which is as common as it is false, *viz.* that *many Things which are true in the Theory, do not answer in the Practice.* But the case is, that a light Sketch of a Design, and general Proportions, are often call'd *a Theory*, which being *incompleat*, will fail in the Practice.

BUT to have a compleat Theory, the Undertaker must understand Bricklayer's Work, Mason's Work, Mill-Wright's Work, Smith's Work, and Carpenter's Work; the Strength, Duration, and Coherence of Bodies; and must be able to draw not only a general Scheme of the whole Machine, but of every particular Part; and small Parts must be drawn by a larger Scale, in order to be fully examined before any thing is begun. Such a Scheme, which the *French* call *Devis*, and expect from their Ingenieurs for the Fortifications of Places, or from the Undertakers of any great Works, are the only full and true Theories. If he who takes in

Lect. XII. hand any great Work, is Mathematician enough to calculate what the Effect of his Power muſt be, deducting what is ſufficient on account of Friction or other Accidents, and has ſo much ſkill in Practice to overlook the Workmen, that there ſhall be no Diligence, Skill, or Honeſty, wanting in the Performance: I dare ſay the Execution will always anſwer ſuch a Theory. I have known ſome Perſons of Fortune, who being covetous, but unwilling to own it, full of the Notion of the Difference between Theory and Practice (or excus'd by it) have hearken'd to the moſt ignorant Pretenders, who have call'd themſelves *Men of Practice*, in order to ſave Money, when they have wanted Water to be raiſed, which they ſuppos'd thoſe who were eminent for their Knowledge that way would expect; and thought that Work done *well enough* and *very cheap* might be ſufficient, as if raiſing of Water requir'd no more Skill than Hedging and Ditching. Thus many People employ the Apothecary to ſave the Charge of the Phyſician.

About 3 or 4 Years ago, there was one *Hugh Roberts* (whom, by his Ignorance, I ſuppoſe to have been a Horſe-Driver at ſome Coal-Pit in *Wales*) who, boaſting of his great Skill in Water-Works, (far beyond what was poſſible) drew in a great many Gentlemen to advance him Money, and got leave to pump the Water out of *Roſamond*'s Pond in St. *James*'s Park, as a Specimen of what he was able to do; but that Performance, and the Repayment of the Money, will come at the ſame time. I know five or ſix Perſons who have been taken in that way, even after I had told them that the Perſons applying to them were ignorant Pretenders. What they loſt by them, and reading this, will make them remember it. Theſe bold Undertakers, who are generally Perpetual-Motion Men, are ſo ignorant as not to underſtand the Language whereby they ſhould be ſhewn their Error; and I have known but one of five and thirty who has been convinced that he was in the wrong in his Scheme for a perpetual Motion.

But to prevent any Perſon from being impos'd upon for the future, in relation to Mills or Water-Works, I will, in this Chapter, ſhew the *Maximum* in theſe caſes; that is, ſhew how much Water can be raiſed to a certain Height in a certain Time, by ſuch a Stream of Water ſtriking againſt a Wheel, or by a certain Number of Men or Horſes. Then People may be aſſur'd, that whoever pretends to have found out an Engine that ſhall do more than in ſuch Proportions, either deceives himſelf, or would deceive others.

After what I have ſaid now, and in my Account of Pumps in this Volume, the Reader will find, that for Machines in which no time is to be loſt, and therefore the moſt is to be made of the Power; ſuch as Machines work'd

work'd by Water, or to raiſe Water, an Account of 15 or 20 of the beſt extant, will be as ſufficient for his Inſtruction, as if we had given 100; the reſt being only Matter of Curioſity. It does indeed happen in Engines, that are not hydraulick ones, that ſometimes we cannot afford to loſe time, tho' we are oblig'd to do it upon other occaſions. In ſuch a caſe, we muſt take care that one Operation of an Engine, is not an hinderance to another Operation of it; otherwiſe we ſhould not aim at two different Effects. A ſhort Account of the Crane at *Briſtol* will ſhew what is to be done in that caſe. The great Crane ſet up there by the late Mr. *Padmore* is mov'd by a very ſmall Trundle or Lantern, whoſe Rounds take the Cogs of a very large Wheel, ſo as to have the Power of two Men ſufficient to raiſe the heavieſt Goods out of a Ship, ſpending the Time neceſſary in the Operation: But as there are a great many Bales of Goods 5 or 6 times lighter than the heavieſt Goods, and it would be Loſs of Time to employ the Crane in the manner already deſcrib'd to raiſe them; there is a Contrivance to looſen the Lantern or Trundle from the Cogs, and then the Wheel being alſo a walking Wheel, the ſame Men get into it, in which caſe they have Power ſufficient to raiſe the ſmall Goods 5 or 6 times faſter than the heavieſt; ſo that the Crane becomes of general uſe. Lect. XII.

IN Works where we are confin'd to Time by Tides, as in making and mending Bridges, there muſt be great care to huſband the Power ſo well as to loſe no time. The late Mr. *Vauloüé*, Watch-Maker, contriv'd the beſt of that kind that perhaps was ever ſeen, and about 5 times more expeditious than the beſt I ever heard of. It has been and is ſtill in uſe at the new Bridge at *Weſtminſter*; and tho' I intended only to give the Reader Hydroſtatical and Hydraulick Engines in this Chapter, I ſhall begin with this for its Excellency.

A Deſcription of the late Mr. Vauloüé's *new Engine for driving Piles.*

REFERENCES.

A. THE great Shaft, on which are the great Wheel and Drum. Plate 26.

B. THE great Wheel with Cogs that turns a Trundle-Head with a Fly to prevent the Horſes falling when the Ram is diſcharged.

C. THE Drum on which the great Rope is wound.

D. THE Follower (with a Roller at one Corner) in which is contain'd the Tongs that take hold of the Ram, and are faſten'd to the other End of the great Rope which paſſes over the Pulley, near the upper End of the Guides, between which the Ram falls.

E. THE inclined Planes, which ſerve to open the Tongs, and diſcharge the Ram.

Lect. XII. F. THE ſpiral Barrel that is fix'd to the Drum, on which is wound a Rope with a Counterpoiſe, to hinder the Follower from accelerating, when it falls down to take up the Ram.

G. THE great Bolt which locks the Drum to the great Wheel.

H. THE ſmall Leaver, which has a Weight fix'd at one End, paſſes through the great Shaft below the great Wheel, and always tends to puſh the great Bolt upwards and lock the Drum to the great Wheel.

I. THE forcing Bar, which paſſes through the hollow Axis of the great Shaft and bears upon the ſmall Leaver, and has near the upper End a Catch, by which the crooked Leaver keeps it down.

K. THE great Leaver which preſſes down the forcing Bar, and diſcharges the great Bolt, at the time the long End is lifted up by the Follower.

L. THE crooked Leaver, one End of which has a Roller, which is preſs'd upon by the great Rope; the other End bears upon the Catch of the forcing Bar, during the time the Follower is deſcending.

M. THE Spring that preſſes againſt the crooked Leaver, and diſcharges it from the Catch of the forcing Bar, as ſoon as the great Rope ſlackens and gives liberty to the ſmall Leaver to puſh up the Bolt.

BY the Horſes going round, the great Rope is wound about the Drum, and the Ram is drawn up till the Tongs come between the inclined Planes; where they are opened, and the Ram is diſcharg'd.

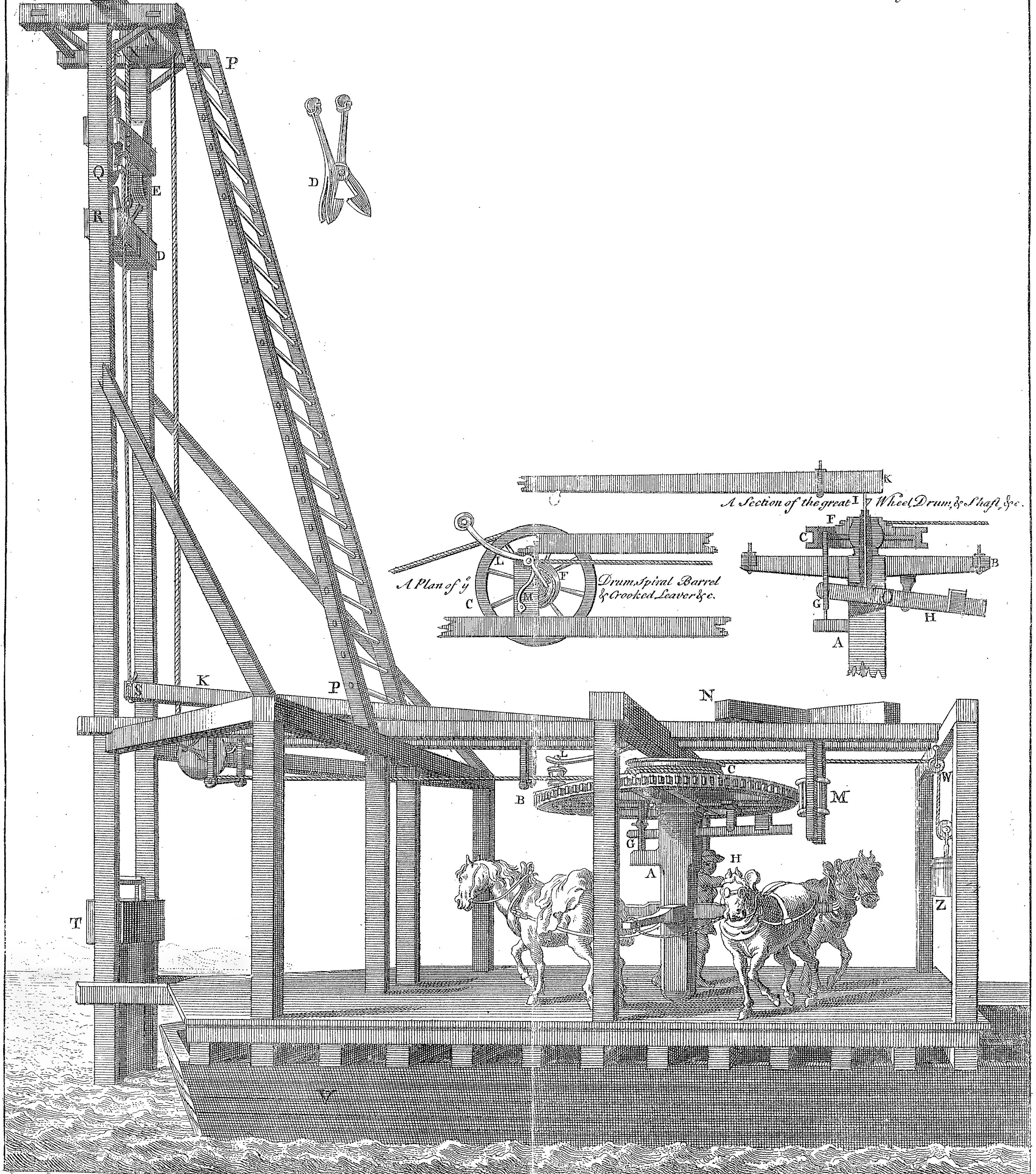
IMMEDIATELY after the Ram is diſcharg'd, the Roller which is at one End of the Follower takes hold of the Rope that is faſtned to the long End of the great Leaver, and lifts it up; the other End preſſes down the forcing Bar, unlocks the Drum, and the Follower comes down by its own Weight.

AS ſoon as the Follower touches the Ram, the great Rope ſlackens, and the Spring (M) diſcharges the crooked Leaver from the Catch of the forcing Bar, and gives liberty to the ſmall Leaver, to puſh up the great Bolt, and to lock the Drum to the great Wheel, and the Ram is drawn up again as before.

SECTION II.

WHEN I gave Practical Rules for *Jets d'Eau* in Page 128, 129, and *ſeq.* I gave a Method for meaſuring the Quantity of Water ſupply'd by a Reſervoir, Spring, or a Collection of Springs; but ſince I have here undertaken to ſpeak of Mills or Machines mov'd by great Quantities of Water, as great Brooks, Parts of Rivers, and ſometimes whole Rivers—. That nothing may be undertaken at random, I think proper here to ſhew how to meaſure the Quantity of Water ſupplied by Rivers; that whether

Plate XXVI
front.^e p. 418.



J. Mynde sc.

whether Part of a River, or the whole be employ'd, the skilful Mechanick (or *Machinist*) may know what Power he uses, and with it produce the greatest as well as the most convenient Effect. There are many ways of measuring what Quantity of Water Rivers afford; but one of the easiest, and exact enough for Practice, is the following, which I shall give without examining into the Theories on which it is built. Lect. XII.

OBSERVE a Place where the Banks of the River are steep and parallel, so as to make, as it were a Trough for the Water to run thro' (like the Boarded-River near *Islington*, as the New River is there called) and by taking the Depth across get a true Section of the River: Stretch a String at right Angles over it; and at a small distance from it another parallel to the first; then taking an Apple, Orange, or any Ball, but just so much lighter than Water as to swim in it, and throw it into the Water above the Strings; observe when it comes under the first String, and measure the Time it spends in coming from the first to the second String (by means of an half-second Pendulum, a Stop-Watch, or any other good Instrument for measuring a small Part of Time) to give you the Velocity of the Water, (which taken at top is sufficiently exact) then try if the Trough or Channel be even, by taking the Depths of the Water to find its Section; and if this 2d Section be equal to the first, all is right; but if it be bigger or less, add it to the first Section, and take half their Sum for a mean Section. This mean Section multiplied by the Length run will give you the solid Quantity of Water running thro' that Section in the time, which you have been measuring, suppose 10 Seconds: then having reduc'd your Solid of Water to Tuns, say thus by the Rule of Three; If 10 Seconds:

Give so many Tons of Water ::

What will 3600 Seconds, or one Hour give?

THE Part of the Channel under a Bridge is generally best for this, because the Breadth of the River is equal, and commonly the Channel under the Bridge all of a Depth, and the Velocity of the Surface of the Water, the Mean of all other Velocities.

THE Example here is as I took it in the Year 1719, to find the Quantity of Water of the *Cowley* Stream, one of the Branches of the *Uxbridge* River; which was propos'd to be brought to *London*, to supply the Deficiency of Water so much wanted since the Increase of the New Buildings.

THE Part of the River cover'd by the Bridge was 10 Foot long.

THE Length of the Bridge, or rather the Breadth of Water under it, 20 Foot.

THE Depth of the Water every where from Side to Side 3 Foot.

Lect. XII. THE Velocity, or Time in which Oranges and Apples ran the 10 Foot, was 10 Seconds

MULTIPLY 20 Foot the Depth of the River, by the Depth of the Water 3 Foot, and you will have the Section 60; which again multiplied by 10 Foot, the Length run, will give you 60, the Number of cubick Feet in that Solid of Water which runs thro' the Section taken in 10 Seconds. Then say

If 10 Seconds :	10 : 600 : 3600
Give 600 cubick Feet of Water : :	600
What will 3600″, or an Hour give? :	10 ÷ 216000|0

Answer. 216000 cubick Feet of Water.

DIVIDE that Number by 34,68, the cubic Feet in a Ton, and you will have 6228 Tons per Hour, which that River gives.

N. B. IF you have but one Section of the River (provided the Water runs equally swift in every Part of it,) and the exact Velocity of the Water in that Section, your Solution will be exact.

HERE I cannot forbear mentioning a false Solution given of the Quantity of Water supplied by this Stream, before a Committee of the House of Commons, appointed to look into the Merits of the Proposal for bringing Water to Town; to shew how much pains People may take to be in the wrong.

A PERSON who call'd himself a Mathematician brought by the Opposers of the Bill, said that I had made the Quantity of Water a great deal too much, as he could shew by a Scheme representing the Experiments he had made. He had taken 320 Foot, to have a sufficient Length, as he said was necessary, on which he had measur'd a mean Velocity, and several Sections in that Space, of which he had taken the Mean, and consequently must be more exact than me who had taken so small a Length of the River: and that his Method gave but about 3000 Tons *per* Hour.

NOW his Method might give more or less almost in any proportion, as I shall shew; and therefore the Testimony given according to it, might very well serve a Turn. We'll prove this by the Example; but first we are to take notice, that thro' every Section of a River there passes the same Quantity of Water in the same time, the Motion being quickest where the River is shallowest; and proportionably slower where it is deepest.

Plate

Plate 27. Fig. 3.

LET the third Figure of *Plate* 27. represent the Bed of the River, AF the Surface, and *adbecf* the Bottom: so that the different Depths are represented by the Curve Line above-mention'd. Let A*g*, D*h*, B*i*, E*k*, C*l*, and F*m*, represent the Breadth of the River at several Sections, each of which (to avoid Fractions) we will suppose every where of the same Depth. Let the Length AF be equal to 320 Feet, and let the Time of the Water running that Length be 400″.

First, LET us take the mean Section of the three in the shallowest Places. *1st*, The River at A is 2 Foot deep and 20 Foot wide, which gives a Section of 40 Feet, because of $2 \times 20 = 40$.

Secondly, THE River at B being 18 Foot wide, and 1 Foot 8 Inches deep, gives a Section of 30 Feet, because $1\frac{2}{3} \times 18 = 30$.

Thirdly, THE River at C being 21 Foot wide and $2\frac{1}{2}$ Foot deep, gives a Section of $52\frac{1}{2}$ Feet, because $2\frac{1}{2} \times 21 = 52\frac{1}{2}$.

THESE three Sections added, and the third of that Sum taken for a mean Section, we shall have $40\frac{1}{2}$ Feet.

THEN we multiply 320 Feet the Length taken, which the Water runs thro' in 400 Seconds, which gives in cubic Feet the Solid of Water passing thro' a Section of the River in 400″, if this Method was right; but Trial will shew it false $320 \times 40\frac{1}{2} = 12960$.

If 400 Seconds
Give 12960 cubic Feet of Water ::
What will an Hour, or 3600 Seconds give?
Answer. 116640 cubic Feet, or $3363\frac{3}{10}$ Tons.

BUT if three Sections had been taken in deep Places, as for Example at D, E, and F, every thing else remaining the same; the Quantity of Water would have come out greater in proportion as the mean Section of those three would have been greater than the mean Section of the shallow ones.

$$\left.\begin{array}{l}\text{The Section at D is} = 200\\ \text{The Section at E} = 162\\ \text{The Section at F} = 160\end{array}\right\}$$

The mean Section therefore is = 174;

Therefore, As $40\frac{1}{2}$ the Mean of the shallow Sections :
Is to 174, the Mean of the deep Sections ::
So is $3363\frac{3}{10}$ Tons :
To 14457,2 Tons,
Which is more than double my Quantity, *ergo*, &c.

Section III.

1. THE mechanical Reader has now full Instructions how to judge of the Quantity of his Power, and what Part of it he intends of make use of. Now for the Application of it, we will first consider how Water works upon an Undershot Wheel, as it is used for grinding Corn, performing Variety of Work in several Manufactures, and raising Water for supplying Towns and Gentlemen's Seats, &c. But especially because we know what the *Maximum* is here, and before we set up an Engine to be mov'd by an Undershot Wheel, knowing the Power, we know the utmost that can be done.

2. The next thing to be done, when we wou'd fix up a Wheel, is to consider whether the Water can run off clear from the Wheel, so as to have no Back-Water to stop its Motion; and what Fall we can have to give the Water coming thro' a Penstock, a Velocity sufficient to strike the Ladle-Boards of the Wheel with a determinate Force.

3. If then we have the Fall of the Water; that is, the Height above the Center of the Ajutage, or of the Opening thro' which it is brought by the Penstock, we must know what will be the continual Velocity of the Water issuing out.

Again, we sometimes have the constant Velocity of the Water, and have occasion to know what Height produces that Velocity. Now these we may know at any time by one single Rule, and an easy Arithmetical Operation.

4. The first Thing requir'd is this:

1. *The perpendicular Height of the Fall being given in Feet and Decimals of Feet; the Velocity the Water will acquire per Second express'd in Feet and Decimals, may be found by the following*

Rule.

Multiply this constant Number 64,2882 by the given Height; and the square Root of the Product is the Velocity requir'd.

Example 1.

If the Height is two Foot, the Velocity will be found 11,34 Foot *per* Second nearly.

Example 2.

If the Height is 16,0913 Foot; the Velocity will be 32,1826 Foot *per* Second, as has been shewn before.

Example

Example 3.

If the Height given is 50 Foot; the Velocity will be 56,68 Foot *per* Second.

The ſecond Thing requir'd is this:

2. *The uniform Velocity of a Fluid being given, expreſs'd in Feet and Decimals of Feet, per Second: the Height of the Fall to produce ſuch a Velocity will be found by the following*

Rule.

Multiply the given Velocity into it ſelf, and divide the Product by 64,2882: the Quotient will be the Height requir'd expreſs'd in Feet, *&c.*

For Example.

If the Velocity given is 3 Foot *per* Second; the Height will be 0,139 of a Foot.

Example 2.

If the Velocity given is 32,1826 Foot *per* Second; the Height will be found 16,0913 Foot.

Example 3.

Let the Velocity be 100 Foot *per* Second; the Height will be 155,549 Foot.

N. B. *The Reaſon of the two foregoing Rules will be demonſtrated in the Notes* *.

Furthermore, if it be requir'd to know with what Quantity of Motion, Momentum, or Impulſe, a Fluid moving with a given Velocity, ſtrikes upon a fix'd Obſtacle, (ſuppoſe a Foot ſquare) find the Height of the Fall that would produce that Velocity by the laſt Rule, and multiply that Height by 62,5 Pounds Avoirdupoids, if it be clean River Water: 63 Pounds for very dirty Water, and 64 *lb.* for Sea-Water. * Ann. 13.

Example.

Suppose a Stream of clear Water to go at the rate of 3 Foot in a Second, meeting with a fix'd Obſtacle 6 Foot wide and two Foot high: the momentary inſtantaneous Preſſure or Impulſe will be found as follows;

The Height that would produce ſuch a Velocity will be found by the laſt Rule = 0,139 of a Foot; which being multiplied by 62,5 ℔. the

Lect. XII. the Product gives 8,6875 upon each square Foot, which being multiplied by 12, the Number of square Feet in the Obstacle, the Product is 104, 25 lb. going with the given Velocity of 3 Foot *per* Second.

5. The Knowledge of the foregoing Particulars is absolutely necessary for setting an Undershot Wheel to work; but the Advantage to be reap'd from it would be still Guess-work, and we should be still at a loss to find out the utmost it can perform, if we had not an ingenious Proposition of that excellent Mechanick Mons. *Parent* of the Royal Academy of Sciences, who has given us a *Maximum* in this case; by shewing, *That an Undershot-Wheel can do the most Work, when its Velocity is equal to the third Part of the Velocity of the Water that drives it.*

6. To make this plain; let us consider that if a Wheel does no work, being *in æquilibrio* and its Gudgeons turning very freely, it will soon move as fast as the Water that strikes against its Ladle-Boards, which will go (for example) three Foot in a Second, if the Velocity of the Water be such. Then suppose that by its Geers the Wheel be apply'd to do Work, there may be so much given to it, that it may have so much Resistance as to stand still, so that the whole Impulse of the Water cannot carry it forward. Then if the Resistance be diminish'd by degrees, the Wheel will begin to move; and increase its Velocity, as its Work is lessen'd. Now as the Work may be too much lessen'd, the Wheel may come to go too fast, and therefore not perform enough.

Mons. *Parent* has shewn that when the Wheel goes with one third of the Velocity of the Water, it is capable of doing the most work; because then $\frac{2}{3}$ of the Water is employ'd in driving the Wheel with a Force proportionable to the Square of its Velocity.

If we multiply the Surface of the Ajutage or Opening by the Height of the Water, we shall have the Column of the Water that moves the Wheel. The Wheel thus mov'd will sustain on the opposite Side only $\frac{4}{9}$ of that Weight, which will keep it *in æquilibrio*; but what it can move with the Velocity it goes with, will be but $\frac{1}{3}$ of that Weight of *Æquilibrium*; that is $\frac{4}{27}$ of the Weight of the first Column, which Resistance the Wheel is capable of overcoming by grinding Corn, lifting Hammers, raising Water, or doing any other Work. This is the utmost that can be expected, tho' often less is done; because here we suppose every Part exactly perform'd, and the Water apply'd in the best manner: therefore as we can never come up to the *Maximum*, we must come as near it as we can, by losing the least we can of the Power's Impulse.

7. It is no Advantage to have a great number of Float-Boards, (or Ladle-Boards, as some call them) because when they are all struck by the Water in the best manner that it can be brought to come against them, the Sum of all the Impulses will but be equal to the Impulse made against one Float-Board at right Angles, by all the Water coming out of the Penstock thro' the Ajutage or Opening, so as to take place on the Float-Board. But as this Float-Board (which when it remains in its Place sustains the whole Weight of *Æquilibrium*, or $\frac{4}{9}$ of the Weight of the Water that acts upon the Wheel) must move forward with Force enough left to carry $\frac{1}{3}$ of the said $\frac{4}{9}$, or $\frac{4}{27}$, there must be a Succession of Float-Boards to receive the Impulse of the Water; and as they cannot immediately receive it at right Angles, there will be some loss of Impulse in that Succession. Besides, when the first Float-Board is so far past the Perpendicular as to have the Push of the Water intercepted by the succeeding one, it is check'd by the Back-Water thro' which it must pass in rising out of the Water, and thereby be so far retarded as to take from the full Effect of the Impulse on the following Ladle-Board. Indeed if all the Water fell off after the Stroke, this would not happen; but this can very seldom be brought about in Undershot Mills, especially those built upon Rivers. All the Remedy in this case is, that when you have fix'd upon the Diameter of your Wheel, and the Breadth of your Float-Board, according to the Water you have to come against them, you may have just such a number of Float-Boards, that each one after it has receiv'd and acted with its full Impulse, may come out of the Water as soon as may be. Lect. XII.

This will be illustrated by examining the 1st, 2d, and 3d Figures of *Plate* 28. The Wheel of *Fig.* 1. has too many Float-Boards. The Impulse here is made directly on the lower Part of the vertical Float-Board C D; but not on the upper Part, by reason of the Interposition of the following Float-Board L E, and therefore D B expresses all that Impulse then made on C B. As the Impulse made on the Part F E of L E is oblique, we must only call F G (the Sine of the Angle E F G) the Impulse on the Float-Board L E, which added to D B will give an Impulse equal to what would strike C B, if L E was not in the way. But as the Float-Board I H, which was acted on in the Direction of the Water, represented by the Dart, is now no longer impress'd in that Direction, but pushes the Water before it with a Force like G H, that Force becomes a negative Quantity, and must be substracted from C B, the Sum of the Forces then acting on the Wheel. Plate 28. Fig. 1, 2, 3.

But if there be a less number of Float-Boards, as in *Fig.* 2. so dispos'd as when C B is vertical, the preceding Float-Board G is just come

Lect. XII. Plate 28. Fig. 2, 3.

clear out of the Water, and the following one L G is juſt coming in, you have the full Impulſe upon C B; and as C B going on recedes from the right Angle, and therefore receives a leſs Impreſſion, beſides what it loſes by the Water's being intercepted from ſtriking it at top, it will receive ſome recompenſe by the Impulſe made on that Part of L E which comes into the Water, to be eſtimated according to the Sine of the Angle in which the Float-Board L E receives its Stroke. This Force is a variable Quantity encreaſing and diminiſhing, and always to be added to the Remainder of Force in C D; but it will never be equal to the Impulſe, which C B receives when vertical. The third Figure ſhews when the Impulſe is leaſt of all, when the Number of Float-Boards is rightly regulated. When two of the Float-Boards are equally diſtant from the Perpendicular F G, the leading Float-Board L receives no Impulſe, being wholly intercepted by the following one C B; and C B being ſtruck obliquely has its Impulſe only as E B, the Sine of the Angle E B D: therefore the whole Impulſe then is but as F N = E B = F G — N G. Thus will the Impulſe on the Underſhot Wheel be always fluctuating between the Quantities F G and F N; not reckoning how much more is to be deducted for the Reſiſtance of the Back-Water.

This is therefore all the Effect we can have, which we muſt be contented with: and that we may have it, or come as near to it as we can, it will not be amiſs to give the beſt number of Float-Boards for a Wheel of any Diameter, when we have reſolv'd on what Breadth to give the Float-Boards. N. B. *The Length of the Float-Boards has nothing to do here, being only according to the Breadth of a Stream that we would make uſe of.*

Mr. *Pitot*, of the *Royal Academy of Sciences at Paris*, has given us a Table, whereby knowing the Radius of an Underſhot Wheel, and the Breadth to be given the Float-Boards, their Number may be found.

Number of Float-Boards.

4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. 20.

Breadth of the Float-Boards.

1000. 691. 500. 377. 293. 234. 191. 159. 134. 114. 99. 86. 76. 67. 60. 54. 49.

This Table is calculated for a Radius divided into 1000 equal Parts: And the Figures in the ſecond Line expreſs the Number of thoſe Parts to be given to the Height or Breadth of the Float-Board. For example, if we would know how many Float-Boards of two Feet wide a Wheel

Wheel of ten Feet Radius must have, you must work it by this Rule of Proportion. Lect. XII.

If 10 Feet, Radius of the Wheel propos'd:
Give 1000 for the Tabular Radius::
What will two Feet, the Height of the propos'd Float-Boards:
Give for the Number of the Tabular Floats, which will give the Number of 200.

Now seek the nearest Number to that in the second Line of the Table; and you will find 191, and the Number which is set over it is 10, namely, the Number of Float-Boards to be given to your Wheel.

8. All necessary Instructions being thus given for erecting of Mills, whether for grinding Corn, working Manufactures, or raising Water, &c. I proceed to give the Description of several useful Machines upon these Principles, and begin by giving the Description of an Undershot Corn-Mill from Mons. *Belidor*.

Section IV.

A Great many Persons may imagine that it is hardly worth while to write about so common a thing as a Corn-Mill; but the Commonness of it shews its Usefulness; and therefore I shall begin without any farther Apology.

1. Few People are ignorant that Corn is ground by two Mill-stones plac'd one above another without touching. The lower or *nether* Mill-stone is immoveable, but the upper one turns upon a Spindle. As this last is susceptible of several Remarks which are commonly overlook'd, before we go on we must take notice of what follows.

The opposite Surfaces of the two Stones which act to grind the Corn, are not *plane* or flat, the upper one is hollow, and the under one swells up, each of them being of a conic Figure, whose Axis indeed is very short in proportion to the Diameter of its Base; for the first having six Feet in Diameter is hollow'd but about one Inch at its Center, and the second rises but about $\frac{3}{4}$ of an Inch: so these two Mill-stones come nearer and nearer towards their Circumference, which gives the Corn that falls from the Hopper room to insinuate as far as $\frac{2}{3}$ of the Radius, which is the Place where it begins to be ground, and where it makes the greatest Resistance that it is capable of: the Space between the Stones being in that Place but about $\frac{2}{3}$, or $\frac{3}{4}$ of the Thickness of a Grain of Corn; but as the Millers have the liberty of raising or sinking the upper Stone a little, they can proportion its Distance from the lower one, according as they would have the Flower finer or coarser.

2. There are two Things to be conſider'd in the Effect of a Mill-ſtone that goes round, its *Weight*, and its *Velocity*; its Work depending on its Quantity of *Motion*, which here is *the Product of its Velocity by Part of its Maſs*. I ſay *Part of its Maſs*; for as this Stone turns upon a Spindle, its abſolute Weight is not wholly employ'd in grinding the Corn, and it is not eaſy to determine what Part has the greateſt Share in it; we only know that it is always proportion'd to the abſolute Weight; Experience ſhewing, that if two Mill-ſtones have the ſame Velocities, but unequal Weights, their Effects, or the Quantities of Flower ground in the ſame time, will be nearly in proportion to their abſolute Weights. As Millers are oblig'd to chip, or new cut the Mill-ſtones almoſt every Month, their Thickneſſes, and conſequently their Weights, diminiſh inſenſibly; and when they come to have but three Quarters, or Half of the Thickneſs which they had when new, they produce but three Quarters or Half the Flower which they gave at the Beginning; this is a Fact which all Millers agree in.

3. The *Centrifugal Force* carrying the Corn towards the Circumference, it is natural for it to be cruſh'd when it comes to a Place where the Interval between the two Mill-ſtones is leſs than its Thickneſs; yet the upper Mill-ſtone having a propping Point which it can never quit, it does not clearly appear why it ſhould produce a greater Effect, as it is heavier, ſince if it was always equally diſtant from the nether Mill-ſtone, it could only be capable of a limited Impreſſion; but, as Experience proves the contrary, I have ſuſpected that in the Action of this Stone there muſt be ſomething more than what is uſually taken notice of; and that beſides its circular Motion, it muſt have a vertical Motion. Accordingly, upon examining the Matter more nicely, I found it to be ſo. For the End of the Spindle of the Mill-ſtone reſts upon an horizontal Piece ſix Inches wide, and five Inches deep, about nine Feet long between its Supports: the *elaſtick* Force of this Piece gives the Stone a little Play, or continual Motion along a Vertical, which, tho' ſmall, may yet be ſeen diſtinctly: this is the Cauſe of it.

The centrifugal Force driving, as I have already ſaid, the Grains of Corn from the Center to the Circumference, in making every one of them deſcribe a Spiral, they get in like ſmall Wedges between the two Stones, and cauſe the upper one to riſe a little; then the horizontal ſupporting Piece below being eas'd of Part of the Weight which it bore, ſtiffens up, and endeavours to riſe up to its natural Situation; but a Moment after, the Mill-ſtone having cruſh'd the Corn which ſupported it, the ſupporting Piece is bent down again, and ſo much the more as the Stone is heavier: the Grains of Corn that we ſpeak of, and which could only

only be bruis'd at first, continuing to go towards the Circumference, there to be wholly ground to Powder, are so much more press'd by the Weight of the Stone, as they are squeez'd into a less Space. Lect. XII.

4. As it is the circular Motion of the Mill-stone which brings the Corn out of the Hopper by Jerks, and with a Velocity depending upon that of the Stone, other Grains are always succeeding, which raise it anew, and the Flower just made being no longer press'd is carry'd away into the Boulting Mill by the Circulation of Air that the Mill-stone puts into motion, which makes a whirling there. Now as the two Motions which I have explain'd concur in grinding the Corn, I conclude, that *The Effects of two different Mill-stones are in a Ratio compounded of their Velocity and of their Weight*; and that in general the same Effects would be much less, if the Pivots of the Irons supporting these Stones, instead of bearing upon a springing Piece, had a fix'd Prop: as I prov'd it by causing the horizontal Piece to be wedg'd up at its supporting Place, so that the Mill-stone might have none but an horizontal Motion; and then the Flower prov'd so coarse as to be scarce separated from the Bran.

5. By the *Velocity of a Mill-stone* is to be understood the Way describ'd by one of the Points of its *mean* Circumference, during a certain Time, and observe that that Circumference has for its Radius the two Thirds of that of the Mill-stone. I shall add, that a Mill-stone, at most, ought to go round but 60 times in a Minute, that it may not heat the Flower.

6. I do not say any thing of the greater or lesser Surface of the Basis of several Mill-stones of different Diameters; for provided they have the same Quantity of Motion, they will always produce the same Effect. It is true, that it appears at first that of two Mill-stones of the same Weight, that which has the greatest Base being able to make an Impression upon the greatest Quantity of Corn, should grind the most in the same time; but this does not happen, because if there was equally spread under these Stones a Quantity of Corn proportionable to their Bases, the Weight with which each Grain will be press'd, will only act in a reciprocal Ratio of the Squares of the Diameters; that is, each Grain answering to the greatest Base will be so much less press'd, than each Grain that answers to the least Base; as the Square of the Diameter of this last will be less than the Square of the Diameter of the first: yet the simple Ratio of the Diameters does in some measure affect the Effect of these two Millstones, because their Velocities is in a Ratio compounded of their Radii, and of the Number of Revolutions that they will severally make in the same time.

7.

Lect. XII. 7. THE Diameter of common Mill stones is commonly from five to seven Feet, and their Thickness, 12, 15, or 18 Inches; they last 35 or 40 Years, and when they have been used a long time, so that their Thickness is considerably diminish'd, they are cut anew, to give their Surface a contrary Figure from what they had before; so that what was the upper Mill-stone is made the nether Mill-stone, and may serve many Years in that Position.

HERE Monf. *Belidor* goes on with observing the Manner that he would have the Water-get, or Channel for the Water, made where the Float-Boards go thro', *viz.* that he would have it at first a little wider than the Hole of the Ajutage, and then so close to the Floats that receive the Impression, as to lose no Water between; then after passing the perpendicular Float, to spread and have a great Declivity, to prevent all Hindrance from the Back-Water. N. B. *This is good where the Wheel is work'd from a Reservoir or Collection of Waters; but cannot be practis'd in a River.*

I PASS over many other Directions and Cautions which he gives; because I have been very full upon them all already; and proceed to the Description of the Parts of an Undershot Corn-Mill. *Plate* 27. *Fig.* 3.

8. A B is the Undershot Wheel, upon whose Shaft D is fix'd a Spur or Cog-Wheel (here call'd a Face-Wheel) E, whose Cogs take the Rounds of the Trundle or Lantern G, which carries round the Mill-stone in the Hurst, or round Frame I, containing the nether Mill-stone at N N, and the upper at V V; the Axis fix'd to the upper Mill-stone being the Iron Bar F.

THEY commonly make these sort of Wheels from 12 to 18 Feet in Diameter, the Float-Boards about $2\frac{1}{2}$, or 3 Feet broad in their Length, with an Height of 10 or 12 Inches. The Shaft 15 or 18 Inches Diameter.

THE *Cog-Wheel* is generally eight Feet Diameter, measuring from the middle of the Sole (that is, where the Cogs are put in to take the Rounds of the Trundle) on one side, to the same on the other. The Sole or Rim of this Wheel must be made of two Pieces eight Inches thick, cross'd one over the other, so as to have a Breadth of eight Inches. This Wheel has 48 Cogs four Inches high, and $3\frac{1}{2}$ Inches wide, 2 Inches thick at the End, and $2\frac{3}{4}$ Inches at bottom, because of the Heel. Their Root is twelve Inches long, and $2\frac{1}{4}$ thick, square at top, and reduc'd to an Inch and $\frac{1}{2}$ at bottom.

THE Lantern or Trundle is made of two round Pieces or flat Heads of 22 Inches Diameter, and four Inches thick, in which are set nine Rounds of two Inches and an half Diameter, and 18 Inches high: the Center

Center of theſe Rounds is plac'd upon the Circumference of a Circle of nine Inches Radius, which muſt be taken for the Diameter of the Trundle. The Rounds muſt be made of hard Wood, as wild Pear-Tree, or Crab-Tree. Thro' the Trundle goes an Iron Axis $2\frac{1}{2}$ Inches ſquare, and of an Height proportionable to the Situation of the Mill-ſtones, in reſpect to the Poſition of the Cog-Wheel; it muſt be well faſten'd to the upper Mill-ſtone, and its Bottom muſt be reduc'd to a Pivot of about half an Inch Diameter, which turns in a Socket let in to the Thickneſs of the horizontal ſupporting Piece H. The ſame Dimenſions are given to the Parts of a Wind-Mill.

Here follow the Names and the Meaſures of all the Parts of ſuch a Mill, neceſſary when we would calculate its Effect, which may be eaſily done by thoſe who underſtand Algebra.

a = 8 Feet, Radius of the Water-Wheel.
b = 4 Feet, Radius of the Cog-Wheel.
c = 9 Inches, Radius of the Trundle.
d = 2 Feet, mean Radius of the Mill-ſtone.
f = $\frac{3}{4}$ of an Inch, Radius of the Gudgeons of the Wheel.
h = $\frac{1}{4}$ of an Inch, mean Radius of the End of the Pivot of the Mill-ſtone, or of the Trundle.
p = 200 Pounds, the Force of the Power that turns the Wheel.
q = 1305 Pounds, the Friction of the Centers.
r = 4348 Pounds, the Weight of the Mill-ſtone, and the Trundle and its Axis.
x = the Weight equivalent to the Reſiſtance that the Mill-ſtone meets with in grinding the Corn.

Such a Mill as this having its upper Mill-ſtone of 6 Foot Diameter, and of about 4348 Pounds Weight, and which goes round about 53 times in an Hour, may grind in 24 Hours about 120 *Septiers* of Corn, each weighing 75 Pounds, when the Stone is newly chipp'd or peck'd, and it is of a good Quality; the hard and ſpungy ones being the beſt, *&c.*

Section V.

Here follows a Deſcription of an Engine which plays a Jet at the Right Honourable the Lord *Tinley*'s, at *Wanſtead* in *Eſſex*, without any Reſervoir; the firſt Impulſe being given by Water acting on an Underſhot Wheel. The Draught and Deſcription I had from my ingenious and very good Friend Mr. *Henry Beighton*, of *Griff*, near *Coventry* in *Warwickſhire*; from whom alſo I have had the Draughts, Deſcriptions, and Calculations of four more Engines; and ſome curious Remarks upon Carriages.

Plate

Plate 27. *Fig.* 2.

A Description of the Reverend Mr. Holland'*s Engine at the Lord* Tinley'*s, &c.*

A B. THE Shaft or Axle-Tree of the Engine 24 Foot long, and 24 Inches Diameter.

C C C C. AN Undershot Water-Wheel 30 Foot Diameter; its Ladles 18 Inches broad. The Water-way 18 Inches broad, and 12 deep. The Fall 7 Foot.

D E F G. FOUR moveable Rings or Collars placed on the Shaft, as are particularly describ'd in *Fig.* 4. of *Plate* 28. 3 Foot Diameter, 6 Inches broad.

HIKL. FOUR Forcers, rising and falling alternately by means of those Collars having four Chains fasten'd to the Collars, and the Tops of the Forcers as W X Y Z represents. The Forcer L is cut off, to shew the Chain more plain. As the Collar G moves (with the Wheel and Axis) half round towards you, the Chain Z fix'd at one End to the lower Part of the Collar G at 2, and its other End at the Top of the Forcer L 1, will pull down the Forcer L 1 $4\frac{1}{2}$ Foot; and at the same time a Chain 1 fix'd to the Head of the Forcer L 1, going over a Pulley R, and to the Head of K, pulls up that Forcer K $4\frac{1}{2}$ Foot; by which time the Collar G will have carry'd its Trigger 2 up to the Bar 1, *i*, which will unlock its Trigger, and the Trigger 3 in the Collar F will be brought backward down to Y, and there lock the Collar F. Then the Movement continuing K, will be depress'd $4\frac{1}{2}$ Foot, and the Chain 1, 1, over the Pulley R will raise L $4\frac{1}{2}$ Foot. And thus these two Forcers and Collars continue rising and falling, moving forwards and backwards, locking and unlocking alternately.

AND in like manner the other two Collars D and E move with their Forcers H and I.

BUT to prevent one Collar's moving the backward way, faster than the other moves forward; there is a Gauge-Chain 4 fix'd to the Collar G, passing over another Pulley T to the Collar F at 5, which regulates their Motions. These Chains are lengthen'd or shorten'd by Screws, as occasion requires.

M N O P. FOUR Brass Cylinders, or Pumps, 7 Foot long; the Bores of M and N 6 Inches Diameter, and O P, $7\frac{1}{4}$; having at *llll* each a Valve below, which are for taking in the Water; and at *mmmm*, Valves in the horizontal Parts.

THE Branches *m n*, *m n*, communicate the Water of their two Forcers together by *n n*, and so into one Pipe *o*. Then O is join'd to *o* coming from the other 2, so the whole Water is forc'd along one Pipe,

WHICH makes a *Jet d'Eau* of 70 Foot, and raises the Water to the House above 70 Foot perpendicular.

FORCING up about 95 Hogsheads *per* Hour to the *Jet d'Eau*, and 47 to the Garden. *g h* are two Cisterns supply'd by a Pipe in *p*, to keep the Forcers or Pistons always wet.

a b c d e f is a Frame of Wood to carry the Pulleys Q R S T, and the Bars *i i*, *k k*.

THE Water-Wheel goes about 5 times *per* Minute to work the Water to the House; and but 3 times when the Water is rais'd 80 Foot to the Gardens. One Turn of the Wheel makes 4 Strokes, *viz.* each Forcer 1; A 6 Inches Bore holds in $4\frac{1}{2}$ Foot —— 4.5 Ale Gallons.

$7\frac{1}{4}$ —————————— 8.0

12.5

12.5

One Revolution of the Wheel 25.0

Times *per* Min. 4

100.0

60 Gallons *per* Hour.

63) 6000 (95.3 Hogsheads *per* Hour.

$\frac{1}{2}$.47.6

THE Lock, *Plate* 28. *Fig.* 4, and 5.

ABCD. AN Iron Plate about 21 Inches long, and 5 broad, and near a Quarter of the Circle of the Collar.

E *e*. THE Catch or Tumbler, turning on a Center-Pin at E, about 11 Inches long.

F. THE Holder on a Center-Pin at F; the End E *f*, 3 Inches long, and F *g*, 7 Inches.

G. THE Trigger, with a Shoulder at *g* to hold F in its Place, 8 Inches long.

H. A SPRING placed under it to throw the End *g* into its Notch at, or Shoulder in G.

D. AT D is a Stop to keep E *e* from turning too far, so as just to take in the Holder F at *o f*.

OVER all this is put another Plate like A B C D, which is screw'd down at 1, 2, 3, 4, 5, &c. and the Sides *a a a a* keep the Plates at a due Distance.

Lect. XII. tance. In the upper Rim is a ſliding Plate with a Spring, to keep G in any Poſition it is placed.

THIS Lock is placed within-ſide of the Collar, as may be repreſented in the Part cut off, in the Cavity C A, from whence the Handles *e* and G have liberty to turn out at the Edge of the Collar at the Slits or Grooves *b* and *i*.

THE Collars are made of four circular Pieces of Wood, jointed together like Felloes in a Wheel, 8 Inches deep and 6 broad. On the Sides of which are Plates of Iron as *k*, *l*, *m*, *n*, with Screw-Pins, that faſten it together when it is put into the Notch of the Axle-Tree *a*, *b*, *Fig.* 3.

IN the fourth (*Fig.* 5.) Place of the grand Axle-Tree (at two Foot diſtance each) are Notches cut out 6 Inches broad and $1\frac{1}{2}$ deep, quite round as *a b*, *a*, *b*. In the middle of which is a Notch $1\frac{1}{2}$ Inch broad and 2 deep, quite round as *c*, *d*; having a Staple or Pin as *d*, ſtanding in it ſo that the Catch E may make one half round before it takes hold of the Staple.

The OPERATION. *Plate* 28. *Fig.* 4.

Plate 28. Fig. 4. AS the Axle-Tree of the Wheel is carry'd round from *c* towards D the right Hand, the Catch E having hold of the Pin in the Axis at *d*, carries the Collar along with it; but ſo ſoon as the Trigger G comes to the Beam I, it unlocks it from the Notch *g*, the other End of the Holder ſlips out at *f*, releaſing the Catch, and *e* flies to the Poſition of *k*. So the Axle-Tree goes forward without the Collar, which having done half round, and the Collar pulled retrograde half round (by a Chain from the next Collar) *k* paſſing back under the Beam I is depreſs'd to the ſame Poſition it was at *e*; ſo when G is come to the Beam K below, the Trigger is ſtruck into its former Place, and is faſt lock'd, by which time the Staple at *d* has hold of the Catch again, and go on together as far as I, where it unlocks again.

In this manner all the four work 2 and 2 alternately.

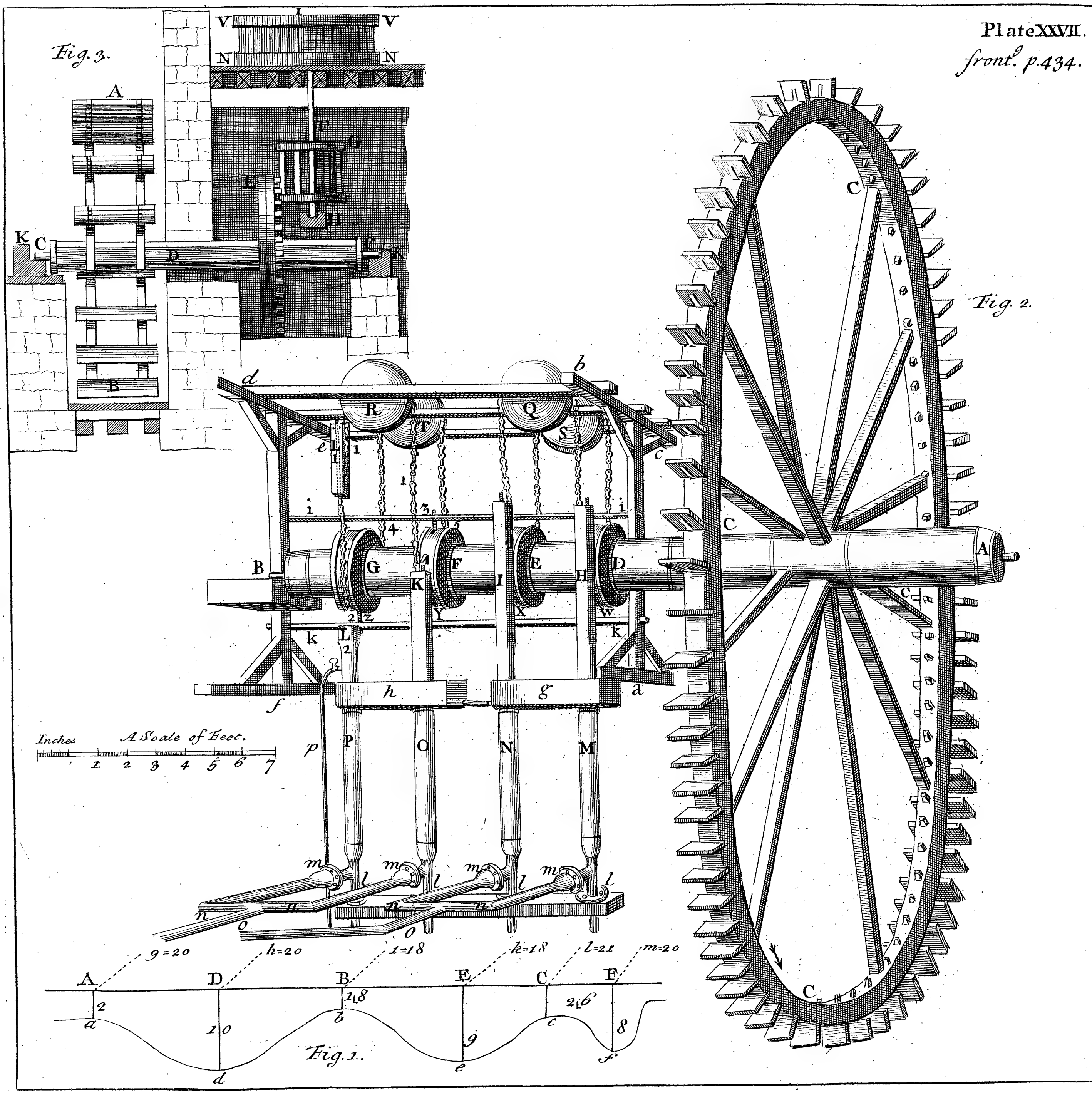
Remarks on Holland's *Engine.*

THE Method of raiſing and falling the Forcers, is what I have not met with in any Treatiſes of Engines.

THE Locks and Collars are ſo curiouſly contriv'd, and the Chains ſo nicely adjuſted, that there's little or no ſhock at the taking and leaving, which ſuch like Works are ſubject to.

The

Plate XXVII.
front. p. 434.



The ERRORS.

1. THE Motion is ſo very ſlow, that a great deal of Water muſt ſlip by the Forcers, unleſs they are very ſtreight-leather'd, and then there are great Frictions.

2. THE lower Parts of the Cylinders or Pumps are ſo ſmall, that there's a great Friction in receiving or filling the Pumps.

3. THE Water in the two 7 Inch Bores or two 6 Inches is all forced through a Pipe of leſs than 3 Inch Bore: So the Friction muſt be prodigious great.

FOR $\left.\begin{array}{r} 7\times7=49 \\ 6\times6=36 \end{array}\right\}=85$, and $3\times3=9$; ſo the Quantity 85 muſt be forced or Wire-drawn thro' 9, and in proportion as 9 to 1. And this Engine might draw double the Quantity if the two laſt Errors were avoided, and if its Velocity was increas'd

95 doubled = 190 Hogſheads *per* Hour doubled,
= 380 *per* Hour.

BUT for the Jet, it is requiſite to force all through a narrow Pipe, or Adjutage. A Wheel well made of 18 or 20 Foot high with the ſame Stream would draw almoſt double the Quantity of Water.

THIS Method of *Holland*'s is not in any reſpect capable of drawing more Water than the common triple Crank-Works, or any Sliding or Bob-Work.

The Velocity of the Water and Wheel.

THE Aperture 18 In. broad. The Fall of the Water about 7 Foot = 84 Inches.
12 deep. A heavy Body deſcends 84 In. in 40‴.
216 ſquare In. In which time a Column double that Height will flow out.

If 40‴—14 Foot — 1 Min.
60
60
3600 ——————
——————3600
40) 50400 (1260 Foot *per* M.

The Circumf. of the Wheel 94 Foot at the beſt goes 5 times round *per* M.
470

470) 1260 (2.68 So the Velocity of the Wheel to the Velocity of the Water is as 1 to 2.68.

Or the Velocity of the Wheel is ſcarce $\frac{2}{5}$ of the Water.

Water expended on the Wheel.

AREA of the Aperture 1,5 F.	This Engine raises *per* H. 95)10800(113 Hogsheads.
1260	So there is expended 113 times as much as it draws.
Cub. Foot Wat. *per* M. 1890	
Gallons in a Foot 6	

63) 11340 Ale-Gallons *per* Min.
(180 Hogsheads *per* Min.
10800 ——— *per* Hour.

Force or Power of the Water, and Engine.

Area Aperture 1.5	Two 7 Inch Bores 70 Foot high Water weighs 2300 lb.
Height Pillar 14	
Cub. Foot —— 210,0	= 20 hundred Weight
in a Foot 6 Gal.	
126 Gal.	1.7 Radius of the Collars.
1 Gal. weighs 10 lb. Aver.	34,0 divided by the Radius of the Wheel 14
112) 1260 (11 Hund.	gives 2 hund. $\frac{1}{2}$.

BUT in Undershot Wheels $\frac{1}{3}$ of that Force is broke and lost, for (1) The Ladles do not fill the Passage; (2) The Ladles or Paddles do not stand close to the Apertures.

Then 3) 11 Hund. (3,6 deduct from 11 remains 7,4 Hund.
The Resistance at the Paddles 2,5
Remains overplus 4,9 hund. Weight,

for the Friction and Velocity of the Engine; which Friction is very great in forcing the Water of 7 Inch Bores thro' 3 Inch Bores, as is observed before on the last Side, Error 3.

N. B. SOME further Remarks of mine upon this Engine will be found in the Notes *.

* Ann. 2.

SECTION VI.

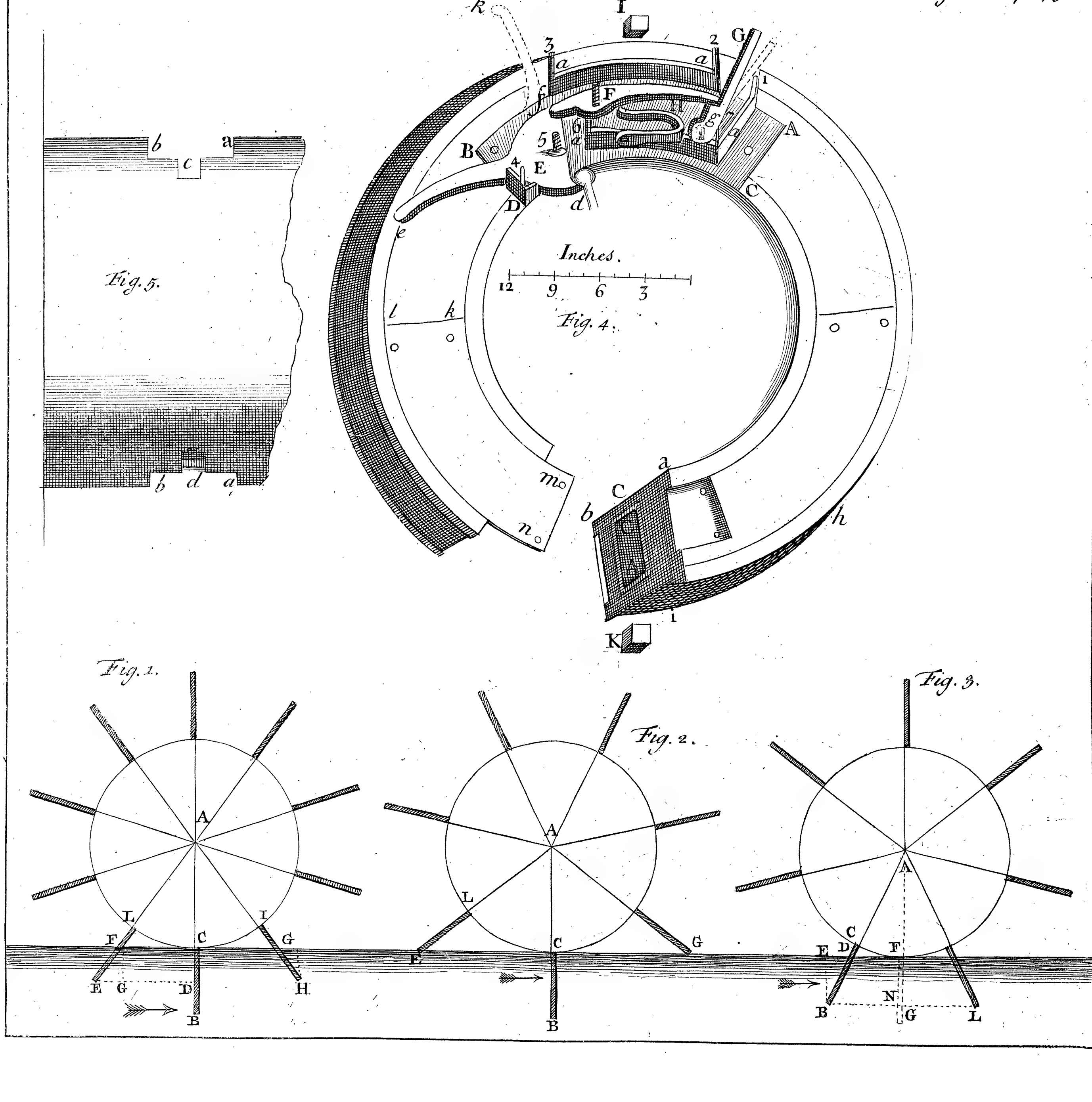
THE next Machine is the *London*-Bridge Water-Works, drawn and describ'd with proper Animadversions by the same curious Gentleman.

A Description of the Water-Works at London-*Bridge, explaining the Draught of* Plate 29. *By* H. Beighton, *F. R. S.*

THE Wheels are placed under the Arches of *London*-Bridge, and mov'd by the common Stream of the Tide-Water of the River *Thames.*

Plate XXVIII

front.[9] p. 436.



AB the Axle-Tree of the Water-Wheel, 19 Feet long, 3 Feet Diameter, in which C, D, E, F, are four Sets of Arms, eight in each Place, on which are fixed G G G G, four Rings, or Sets of Felloes, in Diameter 20 Feet, and the Floats H H H, 14 Feet long and 18 Inches deep, being about 26 in Number.

THE Wheel lies with its two Gudgeons, or Center-Pins A B, upon two Braſſes in the Pieces M N, which are two great Levers, whoſe Fulcrum, or Prop, is an arched Piece of Timber L; the Levers being made circular on their lower Sides to an Arch of the Radius M O, and kept in their Places by two arching Studs fixed in the Stock L, through two Mortiſes in the Lever M N.

THE Wheel is, by theſe Levers, made to riſe and fall with the Tide, which is performed in this manner. The Levers M N are 16 Feet long; from M, the Fulcrum of the Lever, to O the Gudgeon of the Water-Wheel, 6 Feet; and from O to the Arch at N, 10 Feet. To the Bottom of the Arch N is fixed a ſtrong triple Chain P, made after the faſhion of a Watch-Chain, but the Links arched to a Circle of one Foot Diameter, having Notches, or Teeth, to take hold of the Leaves of a Pinion of caſt Iron Q, 10 Inches Diameter, with eight Teeth in it moving on an Axis. The other looſe End of this Chain has a large Weight hanging at it, to help to counterpoiſe the Wheel, and preſerve the Chain from ſliding on the Pinion. On the ſame Axis is fixed a Cog-Wheel R, 6 Feet Diameter, with 48 Cogs. To this is applied a Trundle, or Pinion S, of ſix Rounds, or Teeth; and upon the ſame Axis is fixed T, a Cog-Wheel of 51 Cogs, into which the Trundle V, of ſix Rounds, works; on whoſe Axis is a Winch or Windlaſs W, by which one Man, with the two Windlaſſes, raiſes or lets down the Wheel as there is occaſion.

AND becauſe the Fulcrums of theſe Levers M N, are in the Axis of the Trundle K, *viz.* at M or X, in what Situation ſoever the Wheel is raiſed or let down, the Cog-Wheel II, is always equidiſtant from M, and works or geers truly.

BY means of this Machine the Strength of an ordinary Man will raiſe about fifty Ton Weight.

I, I, is a Cog-Wheel fixed near the End of the great Axis, 8 Feet Diameter, and 44 Cogs working into a Trundle K, of 4½ Foot Diameter, and 20 Rounds, whoſe Axis or Spindle is of caſt Iron 4 Inches in Diameter, lying in Braſſes at each End, as at X.

Z Z is a quadruple Crank of caſt Iron, the Metal being 6 Inches ſquare, each of the Necks being turned one Foot from the Center, which is fixed in Braſſes at each End in two Headſtocks faſtned down by Caps. One End of this Crank at Y is placed cloſe abutting to the End of the Axle-

 Axle-Tree X, where they are at thoſe Ends ſix Inches Diameter, each having a Slit in the Ends, where an Iron Wedge is put, one half into the End X, the other half into Y, by means of which the Axis X turns about the Crank Z Z.

THE four Necks of the Crank have each an Iron Spear, or Rod, fixed at their upper Ends to the reſpective Libra, or Lever, *a* 1, 2, 3, 4, within three Foot of the End. Theſe Levers are 24 Feet long, moving on Centers in the Frame *b b b b*; at the End of which, at *c* 1, 2, 3, 4, are jointed four Rods with their forcing Plugs working into *d* 1, 2, 3, 4, four caſt Iron Cylinders four Feet three quarters long, ſeven Inches Bore above, and nine below where the Valves lie, faſtned by ſcrewed Flanches over the four Holes of a hollow Trunk of caſt Iron, having four Valves in it juſt over *e e e e*, at the joining on of the Bottom of the Barrels, or Cylinders, and at one End a ſucking Pipe or Grate *f*, going into the Water, which ſupplies all the four Cylinders alternately.

FROM the lower Part of the Cylinders *d* 1, *d* 2, *d* 3, *d* 4, come out Necks turning upward Arch-wiſe, as *g g g g*, whoſe upper Parts are caſt with Flanches to ſcrew up to the Trunk *h h h h*; which Necks have Bores of 7 Inches Diameter, and Holes in the Trunk above communicating with them, at which Joining are placed four Valves. The Trunk is caſt with four Boſſes, or Protuberances, ſtanding out againſt the Valves to give room for their opening and ſhutting; and on the upper Side are four Holes ſtopped with Plugs, to take out on occaſion, to cleanſe the Valves. One End of this Trunk is ſtopped by a Plug *i*. To the other, Iron Pipes are joined, as *i* 2, by Flanches, through which the Water is forced up to any Height or Place required.

BESIDES theſe four Forcers, there are four more placed at the other Ends of the Libræ, or Levers (not ſhewn here to avoid Confuſion, but to be ſeen on the left Hand) the Rods being fixed at *a* 1, 2, 3, 4, working in four ſuch Cylinders, with their Parts *d d*, *&c.* *e e*, *f*, *g g*, and *i*, as before deſcribed, ſtanding near *k k*.

AT the other End of the Wheel (at B) is placed all the ſame Sort of Work as at the End A is deſcribed, *viz.*

The Cog-Wheel	I.	The four Levers *a c*, *a c*, *&c.*
The Trundle	K.	8 forcing Rods *a d*, *a d*, *&c.*
The Spindle	X.	8 Cylinders *d e*, *d e*, *&c.*
The Crank	Y, Z.	4 Trunks, ſuch as *e e*, *h h*.
The ſucking Pipes	*f*.	2 forcing Pipes, as *i*.

So that one ſingle Wheel works 16 Pumps.

ALL which Work could not be drawn in one perſpective View, without making it very much confuſed.

A Calculation of the Quantity of Water raiſed by the Engines at London-*Bridge*.

In the 1ſt Arch next the City is one Wheel with double Work of		16 Forcers.
In the 3d Arch	1ſt Wheel double Work at one End, and ſingle at the other	12
	2d Wheel in the Middle	8
	3d Wheel	16
	In all	52 Forcers.

One Revolution of a Wheel makes in every Forcer --- $2\frac{1}{5}$ Strokes.

So that one Turn of the four Wheels makes — 114 Strokes.

When the River is at beſt, the Wheels go ſix times round in a Minute, and but $4\frac{1}{2}$ at middle Water — 6

The Number of Strokes in a Minute — 684

The Stroke is $2\frac{1}{2}$ Feet in a 7 Inch Bore, raiſes 3 } Ale Gall.

They raiſe *per* Minute 2052 }

That is, 123120 Gallons = 1954 Hogſheads *per* Hour, and at the rate of 46896 Hogſheads in a Day, to the Height of 120 Feet.

This is the utmoſt Quantity they can raiſe, ſuppoſing there were no Imperfections or Loſs at all.

But it is certain from the Conſiderations following, that no Engine can raiſe ſo much as will anſwer the Quantity of Water the Cylinder contains in the Length of the Forcer, or Piſton's Motion. For,

Firſt, The opening and ſhutting of the Valves loſe nearly ſo much of that Column, as the Height they riſe and fall.

Secondly, No Leather is ſtrong enough for the Piſton, but there muſt continually ſlip or ſqueeze by ſome Water, when it is raiſed to a great Height; and when the Column is ſhort, it will not preſs the Leather enough to the Cylinder, or Barrel: But eſpecially at the Beginning, or firſt moving of the Piſton, there is ſo little weight on it, that before the Leather can expand, there is ſome loſs.

Thirdly, And this Loſs is more or leſs, as the Piſtons are looſer or ſtraiter leathered.

Fourthly, When the Leathers grow too ſoft, they are not capable of ſuſtaining the Pillar to be raiſed.

Fifthly, If they are leathered very tight, as to loſe no Water, then a great Part of the Engine's Force is deſtroyed by the Friction.

By ſome Experiments I have accurately made, on Engines, whoſe Parts are large and excellently performed, they will loſe $\frac{1}{5}$ and ſometimes $\frac{1}{4}$ of the calculated Quantity.

However

Lect. XII. HOWEVER the Perfections or Errors of Engines are to be compared together, by the calculated Quantities or Forces; for as they differ in those, they will proportionably differ in their actual Performances.

The Power by which the Wheels are moved.

THE Weight of the Pillar of Water on a Forcer 7 Inches Diameter, and 120 Foot high

$7 \times 7 = 49$ lb. The Pounds *Avoirdupoise* in a Yard nearly.
40 Yards high.
1960 lb. on one Forcer.
8 Forcers always lifting.

The whole Weight 15680 lb. = 140 *Ct.* = 7 Tun Weight on the Engine at once.

THEN the Crank pulls the *Libra* 3 Feet from the Forcer, and 8,3 Feet from the Center,

7 Tun
× 11,3
8,3) 79,1 (9,5 Tun on the Crank
Tun.
Wallower 2,2) 9,5 (4,3 on Trundle.
The Spur Wheel 4
The Radius of the great Wheel 10) 17,2 (1,72 Tun.
20
The Force on the Floats 18 *Ct.* 40 lb. 34,40 *Ct.*

BUT to allow for Friction and Velocity, may be reckon'd 1 Tun $\frac{1}{2}$.

THE Ladles or Paddles 14 Foot long, 18 Inches deep } = 22,4 square Feet.
THE Fall of Water is at a Mean 2 Feet.
44,8
6 Gal. in a Cub. Foot.
)268,8
10 lb. in a Gallon.
112) 2688 (24 Hundred.

The Velocity of the Water, 4 Feet in 21‴ of Time.

21‴ — 4 Ft. :: — 60″ : = 685 Feet *per* Minute.

THE Velocity of the Wheel = 310 Feet *per* Minute.

QUANTITY expended on the Wheel, according to the Velocity of the Stream 1433 Hogsheads *per* Second.

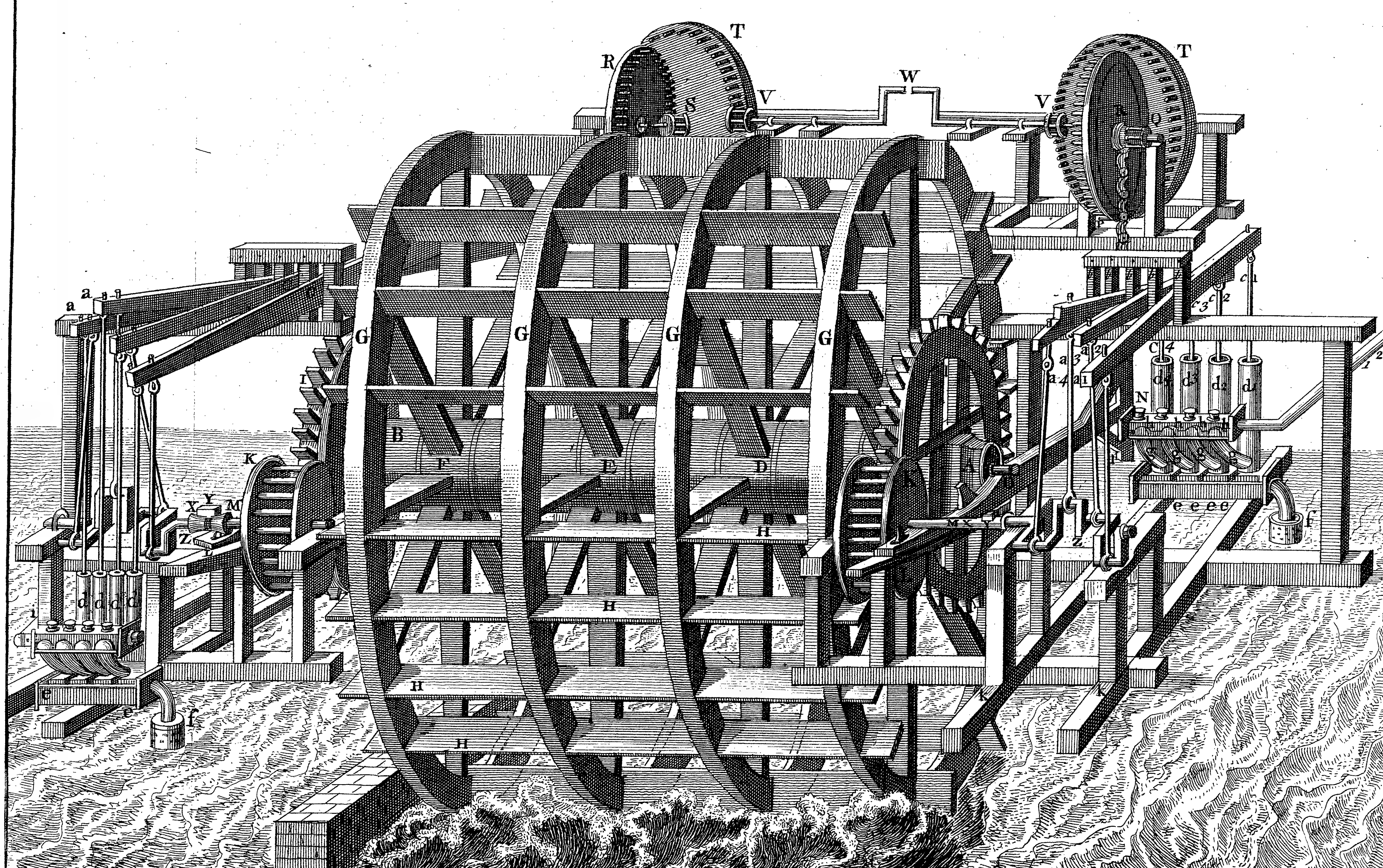
BUT at the Velocity of the Wheel 645 Hogsheads *per* Second.

THE Velocity of the Wheel to the Velocity of the Water, as 1 to 2,2.

Some

Plate XXIX.

front.^s p. 440.



J. Mynde sc.

Some Observations on these Water-Works.

ALTHOUGH they may justly be esteemed as good as any in *Europe*, yet are there, as I conceive, some Things which might be altered very much for the better.

First, IF instead of 16 Forcers they worked only eight, the Stroke might be five Feet in each Forcer, which would draw a great deal more Water with the same Power on the Wheel; for then there would be but half the opening and shutting of Valves; consequently but half that Loss: And a five Feet Stroke draws above double the Quantity of two Strokes of 2 $\frac{1}{2}$ each, by near $\frac{1}{5}$, in regard the Velocity is double, which is the most valuable Consideration in an Engine, where the Pipes will sustain such Force.

Secondly, The Bores that carry off the Water from the Forcers are too small, there being (nearly) always two Pillars of seven Inches Diameter, forcing into one Pipe of the same Diameter, and $7 \times 7 = 49 + 49 = 98$.

THEREFORE those Pipes of Conveyance should be near nine Inches Diameter.

The Perfections of the Machine.

THE Timber-work is all admirably well performed, and the Composition and Contrivance, for Strength and Usefulness, not exceeded by any I have seen.

THE cast Iron Cranks are better than wrought ones, by reason they are very stiff, and will not be strained, but sooner break; and besides they are cheap, and new ones easily put in.

THE Wedge for putting on or releasing the Crank and Forcers, is better than the sliding Sockets commonly used.

THE forcing Barrels, Trunks, and all their Apparatus, are very curiously contrived for putting together, mending, altering or cleansing, and subject to as little Friction as possible in that Part.

THE Machine for raising and falling the Wheels is very good, though but seldom used, as they tell me; for they will go at almost any Depth of Water, and as the Tide turns, the Wheels go the same Way with it.

THESE Machines at *London-Bridge* are far superior to those so much famed at *Marly* in *France*, in regard the latter are very ill designed in their Cranks, and some other Parts.

H. Beighton, F. R. S.

I SHALL add a few more Remarks to what my Friend has said concerning these Water-Works in the Notes *. * Ann. 3.

SECTION VII.

THE Machine at *Marly* to raiſe Water for the King of *France*'s Gardens at *Verſailles* being ſo much talk'd of, on account of its prodigious Largeneſs, Number of Parts, Expence of erecting it at firſt, and maintaining it yearly; and, in a word, of its Magnificence: I could not omit giving an Account of it here, which I have done from *Monſ. Belidor*.

The MACHINE *of* MARLY. *Plate* 30, and 31.

ONE *Rannequin* of the Country of *Liege*, a Man of an excellent Genius for Mechanicks, was bold enough to undertake to bring Water in as great Plenty to *Marly* and *Verſailles*, as if thoſe Places had been full of original Springs. The Machine or Engine which he made uſe of for that Purpoſe, began to work in the Year 1682. It is ſaid that it coſt above 80 Millions of *French* Livres, (about four Millions of Pounds Sterling.) I have for a great while been unwilling to give an Account of it in this Book, by reaſon of the Difficulty of deſcribing it exactly, and having a good Draught of it. Beſides, the Management of it being ſo expenſive, it appear'd to me to be a ridiculous thing to give it as a Model to ſuch as read my Book to find the means of raiſing Water: but then conſidering that this Machine being famous all over *Europe*, I thought it would be a Satisfaction to the Curious to have particular Deſcriptions of every Part of it. Beſides, ſeveral Pieces of it may be very uſefully copied, and many ingenious Contrivances not to be met with elſewhere may be taken from it.

FOR a long time I ſought in vain for the ſeveral Plans and Profils of this Engine, and all its Parts, knowing it muſt be a tedious piece of work to go upon the Place, and take them myſelf; but at laſt I was ſo happy as to meet with a Friend that had them, and was ſo kind as to communicate them to me. That I might be ſure that they were exact, and to give an exact Deſcription of them, I went to the Machine, where I ſpent eight Days in viewing and examining it, and Mr. *de l'Eſpine* the Comptroller of it explain'd to me every thing that I wanted to know.

THIS Machine is ſcituated between *Marly* and the Village *de la Chauſſée*: in that Place the River is barr'd up partly by the Machine, and partly by a Dam which keeps up the Water; but not to interrupt the Navigation, two Leagues above *Marly* a Canal has been cut for the paſſing of the Boats and Barges: there has alſo been erected 30 or 35 Fathom from the Machine a Contrivance call'd an Ice-breaker, to prevent floating

floating Pieces of Ice or Timber coming down the Stream from damaging the Machine; and the better to ſecure the Penſtocks, and the Gets or Channels in which the Wheels move, there is a Grate of Timber to ſtop whatever may come thro' the Ice-breaker. Lect. XII.

THE Machine has 14 Wheels, which all ſerve to move the Pumps which force the Water up to the Tower at the Top of the Mountain, where coming out of ſeveral Pipes it unites to run into an Aqueduct, which conducts it to the Reſervoirs that receive it: and as it is ſufficient to underſtand all that belongs to one of theſe Wheels, to judge of the Effect of the reſt, (which to deſcribe would be only a Repetition of the ſame Things) I ſhall here explain one, Piece by Piece, not to take in too much at a time.

Plate 30.

THE firſt Figure of *Plate* 30. repreſents the Plan and Profil of one of the Wheels of the Machine, and of the moſt general Parts belonging to it, from the Wheel to the Aqueduct. This Wheel, (*Plate* 30. *Fig.* 2. has a Get ſhut up by a Sluice or Penſtock, as uſual; its Motion produces two Effects, the firſt is to work ſucking and lifting Pumps, which raiſe the Water thro' the Pipe 3 to an Height of 150 Feet into the *Ciſtern* 4, diſtant 100 Fathom from the River: the ſecond is to move the Regulators 5 and 6, which work lifting Pumps placed in the Building 7 and 8. Thoſe that anſwer to the firſt Ciſtern 4, take the Water that has been rais'd up to that Height, and force it thro' the Pipe 10 into the ſecond Ciſtern, 175 Feet high above the firſt, and 324 Fathom from the River: from thence the Water is taken up anew by the Pumps which are in the Building 8, which force it thro' the Pipe 11 up to the Platform of the Tower 12, which is 177 Feet above the upper Ciſtern, and 502 Feet above the River, from which it is diſtant 614 Fathom: from thence the Water runs naturally in an Aqueduct, by the Fall given to it, to the Grate of the Caſtle of *Marly*, whence it deſcends to the great Reſervoirs, which diſtribute it to the Gardens and Groves. Plate 30. Fig. 1, 2.

AT firſt a Ware was made on the River as ſolid as poſſible with Piles and Planks, ſupported with Maſons Work, as is done in like caſes; ſee the third and fourth Figures. Fourteen Feet above this Ware is built a Floor or Bridge, to ſuſtain the Pumps and all that belongs to them, as one may judge by the ſecond Figure, which ſhews that the Arbor or Shaft of the Wheel has two Cranks 13 and 14. This laſt takes a Leader 15, which cannot ſo well be diſtinguiſh'd as in the third Figure, whoſe Pieces you muſt compare with the ſame in the ſecond. At each Turn of the Crank this Leader gives a vibratory Motion to the Regulator 16 on

 its

Lect. XII. Plate 30. its Axis. To this Regulator is fix'd another Beam hanging 17, which is fasten'd to the Regulator 18, at the End of which are two hanging Pieces 19, carrying each of them four Pistons, which work in four Pump-Barrels, mark'd in the Plan by the Number 20.

WHEN the Crank 14, and the Regulator 16 raise the Beam 17, the Pistons which answer to the left of the Balance bring up the Water by the Pipes 21, which dip into the River, while those on the other side lift it up into the Pipe 22, whence it goes into the first Cistern; and when the Crank draws towards its Center the Regulator 16, the Regulator 18 inclining in a contrary Direction to what it did before, the Pistons on the left lift up, and those on the right suck; and this is continu'd alternately.

To prevent the Air from insinuating itself into the Pump-Barrels, and to prevent the Leathers of the Pistons from leaving any Vacuity, to each Engine (or Assemblage of Pumps) has been added, independent of the eight lifting Pumps, a sucking Pump call'd a *Feeder*, to keep a Bason 23, at the Height of the Top of the Pump-Barrels, always full of Water: so that one of the hanging Pieces 19 carries a fifth Piston.

THE Crank 13 gives Motion to the Pumps of the first and second Cistern; and how that is done you must consult the fourth and fifth Figures, with relation to the second: there you will see that the Crank gives a vibratory Motion to the Regulator 25, by means of the Leader 24, which draws to itself, then pushes forward the End 30. This Regulator moves two others horizontally, which are plac'd below the Numbers 28 and 29, by the Motion communicated to them from the Leaders 26, 27, which push or draw the upper or lower Regulator, according to the Position of the Crank.

ONE may see on the Plan how the Regulator 29 can move upon its Axis 32, and that at the End 31 there is a Chain 31, 33, which may be look'd upon as making Part of the Chain 34, 35, express'd in the sixth Figure: likewise the Regulator 28, which cannot be seen upon the Plan, but which is like the lower one, answers also to a Chain which makes Part of the other 36, 37; thus those two Chains are alternately pull'd by the Regulators 28 and 29, to cause the Pumps of the Cisterns to work. These are sustain'd by the Balances 38, fix'd at every 18 Feet, having thro' them Center-Pins, which bear upon the Piece 39 laid on the Blocks of the Props 40.

THE sixth Figure is a Profil, which may be common to the first and second Cistern, but rather belongs to the second than the first, because the Chains end at the Regulators 42, 46, but only pass thro' the first, after having put in motion the Pumps that are in it.

WHEN

WHEN the Chain 36, 37, draws to itſelf from right to left the Regulator 42, that Regulator lifts the Frame 45 ſuſpended at the End 43, having three other Frames 44 that carry the Piſtons which lift the Water in the Pump-Barrels 50, 51. When this Chain ceaſes to be extended, and the lower 34, 35 is drawn, then the Weight of the Frame 45, and that of the Frames and Piſtons, cauſes the End 43 of the Regulator 42 to deſcend, and the Water riſes in the three Pump-Barrels of that Engine: on the other hand, the End 48 of the Regulator 46 lifts the Frame 49, and the Piſtons which are ſuſtain'd by the Frames 42 lift the Water in the three Barrels of this ſecond Engine, which, like the firſt, join to the Pipe 50, 51.

ALL theſe Pump-Barrels are kept unmoveable by Iron Bars that embrace them, as may be ſeen in the Plan of the Ciſtern. I muſt add, that the Pumps which the Crank 13 cauſes to move in the firſt and ſecond Ciſtern, raiſe Water in their Well without having any thing common with the Engines of the other Wheels; that is, that at the Level of the Buildings 7 and 8 in the firſt Figure, there is a Baſon which takes up almoſt the whole Contents of it to make Wells or Ciſterns, in each of which are ſix inverted Pump-Barrels, whereby the Water is only rais'd when it is thought neceſſary; and if any thing is to be repair'd in the Engines I have lately deſcrib'd, the Ciſterns may be let dry, and Workmen go down into them without diſturbing the working of the other Pumps.

IN order to draw the Frames eaſily out of their Ciſterns, when any thing is to be repair'd, a good Contrivance is made uſe of; at the Place 53 is an Axle with a Rope, at one of the Ends of which Axle is a Wheel with Teeth, with a Catch to hinder the Rope from unwinding more than you would have it: the Rope goes over a Pulley 54, and terminates at the Block of another Pulley 55, which may ſlide from one End to the other of the Beam 60, 60. Over this ſecond Pulley runs another Rope, to the End of which is faſten'd the double Hook 56; this Rope afterwards goes over the Pulley 57, and thence terminates at the Axle of a Wheel 58, whoſe Teeth are taken by the Rounds of a Lantern 59, which is carried round by an Handle: by this means one may place the Hook over againſt the Place where you would have it riſe or fall upon occaſion.

As the Pumps which are over the River, and thoſe of the Ciſterns are drawn too ſmall in the Figures above-mention'd, for diſtinguiſhing their Piſtons and Valves; they are drawn in large upon the 31ſt Plate, to make them the more intelligible; as are alſo drawn ſeveral other Pieces that I am going to explain.

THE

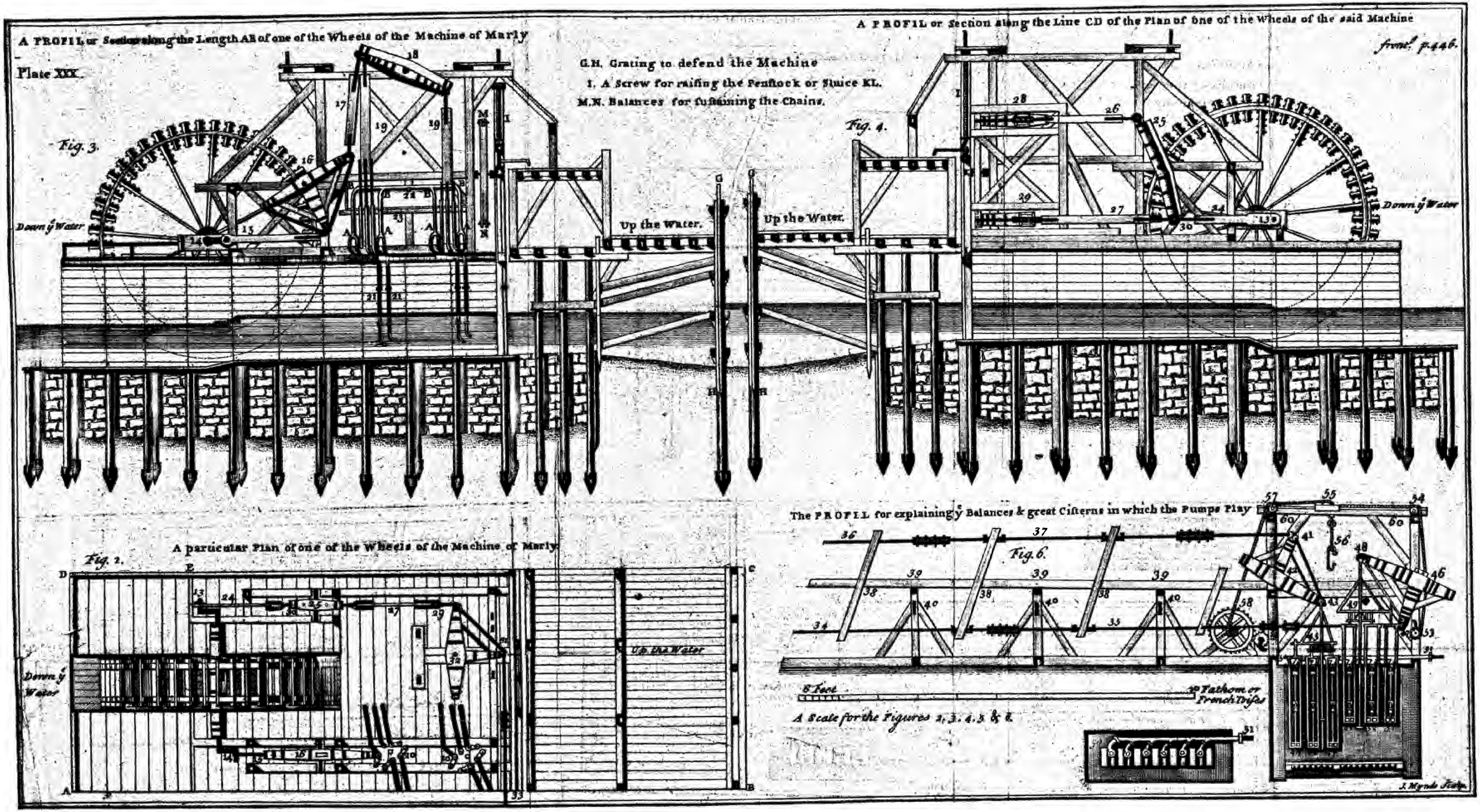
Lect. XII. Plate 31.

THE 20th Figure ſhews the Inſide of one of the eight ſucking and lifting Pumps, which are moved by the Crank 14 of the ſecond and third Figures: when the Piſton 62 riſes, the Water of the River is drawn up by the ſucking Pipe 63, opens the Valve 64, fills the Cavity 65, and Part of the Pump-Barrel 66; and when it comes down, it preſſes the Water which was riſen in the Pump-Barrel to drive it into the Cavity 65, and the Water which is there endeavouring to eſcape every way, does again ſhut the Valve 64, and open that at 67 to go up into the Pipe 68; and when the Piſton ſucks, that Valve ſhuts, and the Clack 64 opens again.

THE Outſide of this Pump is repreſented by *Fig.* 19, which ſhews in what manner the Pipes are faſten'd by Flanches and Screws. The Pipe 69 is re-united to that of another Pump, each of them joining with another Pipe mark'd A in the third Figure, having an Elbow at B to join with the Pipe 22, which has four Branches, two at the right, and as many on the left; the little Circle that you ſee over N° 22, ſhewing the Circumference of that Pipe; conſequently the eight Pipes 69 when re-united make but four, and theſe four again unite into one, which receives the Water of the eight Pumps to convey it to the firſt Ciſtern. As to the ſucking Pump that we have call'd the *Feeder*, and which feeds the Baſon that anſwers to the Orifice of the eight Pump-Barrels; its Inſide is repreſented by the 16th Figure, and has nothing particular, its Piſton 70 being pierc'd like that of common ſucking Pumps, having a Valve to retain the Water which it raiſes, and a Clack 71 to hinder the rais'd Water from falling back. All the Pump-Barrels which I have deſcrib'd, together with their Pipes, are made of Pot-metal, except the ſucking Pipes 63 and 72, which are of Lead.

THE ſeventh Figure ſhews the Inſide of one of the lifting Pumps of the firſt and ſecond Ciſterns, whereby it appears that each Pump-Barrel, ſuch as 73, is carried by Iron Bars ſeen in Profil at 74, and that other Bars 75 hinder thoſe Pump-Barrels from being rais'd up by the Piſton when it makes its lifting Stroke: you ſee alſo that the Rod 76, which carries the Piſton, is faſten'd to two Croſs-Pieces of the Frame 77, and that that Frame and the Piſton riſe and fall with the other Frame 45: at the Places 78 there are Rollers to facilitate the Motion, when you would take away one of the Frames, or put it in again.

THE Piſton of this Pump is hollow, with a Valve that opens when the Frame goes down to give Paſſage to the Water, and ſhuts again when it is lifted; then the Valves 79 and 80 open to let it go into the Pipe 81, which ends in the ſame manner as the other ſix Pipes 50, 51, which go with the ſixth Figure. Laſtly, the eighth Figure ſhews the Outſide


A PROFIL or Section along the Length AB of one of the Wheels of the Machine of Marly
Plate XXX.
G.H. Grating to defend the Machine
I. A Screw for raising the Penstock or Sluice KL.
M.N. Balances for sustaining the Chains.
A PROFIL or Section along the Line CD of the Plan of one of the Wheels of the said Machine
front. p.446.
Fig. 3.
Fig. 4.
Down y^e Water
Up the Water.
Up the Water.
Down y^e Water
The PROFIL for explaining y^e Balances & great Cisterns in which the Pumps Play
Fig. 6.
A particular Plan of one of the Wheels of the Machine of Marly
Fig. 2.
Down y^e Water
Up the Water
8 Feet
10 Fathom or French Toises
A Scale for the Figures 2, 3. 4. 5 & 6.
J. Mynde Sculp.

of this Pump and its Flanches, which ſerve to keep it immoveable upon the Iron Bars to which it is fix'd.

THE 15th Figure is the Profil of a Pipe of Conduct, accompanied with one of its Ends mark'd S, ſeen in Front, to ſhew the Flanches by which the Pipes are join'd to one another with Screws, putting Rings of Lead and of Leather between, to make them tight.

THE 18th Figure repreſents a Valve fix'd at the Bottom of each Ciſtern, to empty it thro' the Pipe 84, which is done by turning the Handle which is at the End of the Rod 83. As for the 17th Figure, it repreſents the Clack which is plac'd at the Top of the Pump-Barrels 87, to hinder the Water which is riſen from coming down again.

THE 9th, 10th and 11th Figures expreſs the different Faces of the End of a Regulator, to which are ſuſpended the Pieces which it puts in motion. You ſee that at that End is an Ear of Iron 85, whoſe Tail which goes three Feet into the Wood is ſhewn by prick'd Lines. This Tail is travers'd with Pins 86, made faſt with Iron Bonds. In this Ear are Braſs Collars, which may be renew'd when the Friction of the Pivots that play in them has made their Bore too wide.

As it might happen that one of the Iron Bars of which the Chains 5, 6, of the firſt Figure are made, might break, and thereby many others might alſo break by the great Force of the Crank that moves them, at every 12 Fathoms, there is a looſe Chain that yields, as the 12th, 13th, and 14th Figures ſhew in ſeveral Views.

HERE follows a general Re-capitulation of the moſt eſſential Parts of this Machine, accompanied with neceſſary Supplements to the foregoing Explanation.

THE Breadth of the Machine comprehends 14 Gets or Water-Courſes, ſhut by Sluices or Penſtocks, which are rais'd and depreſs'd by Racks, and in each of theſe Gets is plac'd a Wheel: theſe Wheels are diſpos'd on three Lines; in the firſt, on the Side which looks up the Stream, there are ſeven, ſix in the ſecond, and only one in the third.

THE Ends of the Axle of each Wheel go beyond their bearing Pieces, and are bent into a Crank, which makes a Leaver of two Feet; and it is to be obſerv'd, that the Crank which is towards the Mountain ſucks and lifts the Water of the River, to drive it into the firſt Ciſtern, and the other Crank gives Motion to the Balances.

SIX of the Wheels on the firſt Line by one of their Cranks give motion to an Engine of eight Pumps, without reckoning the Feeder: theſe Engines are compounded of a Regulator, at each End of which hangs a ſquare Piece of Wood, which carries and directs four Piſtons; the Regulator

Lect. XII. gulator is put in motion by two Beams or Leaders, one of which lying along anſwers to the Crank of the Wheel and a vertical Regulator, and the other hanging down is united to the ſame Regulator and to the Balance.

OF the ſix Wheels which we have mentioned, there are five which by their other Crank give motion to the Pumps that work in the Ciſtern of the firſt Lift, by means of horizontal Regulators and Chains which communicate the Motion. The ſixth Wheel, which is the firſt towards the Dam, moves a long Chain which works the Pumps of one of the Wells of the upper Ciſtern, which is call'd the Ciſtern of the great *Horſes*, (Chevalets). As for the ſeventh Wheel of the firſt Line, each of its Cranks moves a Chain which goes to the firſt Ciſtern.

THE ſix Wheels of the ſecond Line by each of their Cranks move a Chain which goes to the upper Ciſtern, which (reckoning the Chain that comes from the ſixth Wheel of the firſt Line) makes 13 Chains. Theſe Chains go over one of the Ciſterns of the firſt Lift; and there five of them at the ſame time give motion to the Piſtons of thirty Pumps, whilſt the other Chains go on ſtreight to the upper Ciſtern.

LASTLY, the Wheel which is on the third Line, by each of its Cranks works an Engine of eight ſucking and lifting Pumps, and of it ſelf ſupplies one Conduit-Pipe.

THE ſeven Chains of the Wheels of the firſt Line in going along do alſo work eight ſucking Pumps placed a little below the Ciſtern of the firſt Lift, becauſe in that Place there are the Waters of a conſiderable Spring brought thither by an Aqueduct; and theſe ſame Chains take up that Water a ſecond time to force it by 49 Pumps into the upper Reſervoir, thro' two Conduit-Pipes of eight Inches, and three others of ſix Inches Diameter. As to the thirty Pumps of the Ciſtern of the firſt Lift, they drive their Water alſo thro' two Pipes of eight Inches Diameter, which carry it into the upper Ciſtern.

THE Water rais'd at the two Ciſterns in the way up the Hill, diſcharges it ſelf into a great Reſervoir, and thence by two Conduit-Pipes of one Foot Diameter each, it runs into Reſervoirs of Communication to be diſtributed into the ſeveral Wells or little Ciſterns of the upper Ciſtern, whence it is lifted by 82 Pumps thro' ſix Conduit-Pipes of 8 Inches Diameter up into the Tower, which anſwers to the Aqueduct.

THE eight great Chains which go ſtreight to the upper Ciſtern, without moving any Engines by the way, work ſixteen Pumps behind the upper Ciſtern, to bring back into the Reſervoir of the ſaid Ciſtern the Water which is loſt out of the ſix Pipes that go to the Tower.

THE eight Engines which ſuck and lift the Water from the River, contain 64 Pumps; the two Ciſterns in the way up the Hill together contain

79,

79, and the upper Cisterns 82, to which adding the eight sucking Pumps which we have call'd Feeders, and also the eight others which are below the Cistern at Mid-way, and besides the 16 Pumps placed behind the upper Cistern (as we mention'd) we shall find that the Machine has in all 253 Pumps.

THE Bason of the Tower which receives the Water rais'd from the River and supplies the Aqueduct, is 610 Fathom distant from the River, and is 500 Foot higher than the lower End of the sucking Pipes of the lower Engines.

THE Pumps which are upon the River suck the Water 13 Foot high, reckoning from the Bottom of the Water-Gets to the Valves; and then this Water is lifted thro' five Conduit-Pipes of 8 Inches Diameter up to the Cisterns mid-way.

THE Water having run along an Aqueduct of 36 Arches, is separated into different Conduits, which lead it to *Marly*, and formerly led it also to *Versailles* and *Trianon*.

THE Reservoirs of *Marly* have 18700 square Fathoms in Surface, and are 15 Foot deep; that at *Lucienne* has in Surface 24500 square Fathoms, and is also 15 Foot deep.

WHEN formerly the Machine acted with its full Force, and the Waters of the River were high, in 24 Hours the Reservoir at *Marly* was raised three Inches, which makes 779 cubic Toises; but commonly it furnishes but half that Quantity.

THERE are about sixty Workmen who are continually employ'd to take care of this famous Engine, under the Direction of Mons. *de l'Epine*, the Comptroller of it.

N. B. THE Quantity of Water raised by this Engine, reduced to *English* Measure (at 27 Hogsheads to the *French* cubic Toise) comes to 5258 Tons in 24 Hours, or near 220 Tons *per* Hour, or $3\frac{1}{2}$ Tons *per* Minute.

I SHALL give a few Observations upon this Machine in the Notes *. * Ann. 4.

NOW I proceed to give a curious Account of one of the best Overshot Mills in *England*, communicated to me by Mr. *Beighton* abovementioned.

SECTION VIII.

A WATER-MILL, *for grinding Corn, at the* Barr-Pool, *by the Abbey in* Nun-Eaton, *in* Warwickshire. *Plate* 32.

IN the perspective Drawing all care has been taken, to see as much as is necessary to shew the whole Structure of all the useful or moving Parts of the Mill; for which it is laid open or cut in such Sections, as I judged best suited the Purpose. The Scale fits the Orthography or fore-right Side of the Frame or Building; the other Parts perpetually diminishing.

IN which Drawing I have described the Machine by References in the following manner.

REFERENCES.

AB. THE Axle-Tree or Shaft of the Water-Wheel 13 Feet long and 17 Inches Diameter.

CCC. HAVING six Arms fix'd in it at D, 9 Inches broad and 3 thick.

E E. THE Sole of the Wheel is fixed, being 18 Inches broad, and the Shrouds 14 Inches deep; having 30 Buckets. Their Breadth FI $17\frac{1}{2}$ Inches. FG, Depth 19. GH, The Elbow to the Sole 4 Inches.

I K. THEIR Distance from one another 17 Inches and an half. The whole Height or Diameter of the Wheel 16 Feet.

L L. A Cog-Wheel placed on the same Shaft by 4 Arms at M, 7 Feet Diameter, having 48 Cogs or Teeth, which turns

N. A Wallower, Pinion, or Trundle 19 Inches Diameter, of 9 Rounds or Leaves, in which is fix'd an Iron Spindle

NO. GOING thro' the Middle of the lower Mill-stone P, moving in a Collar, to which is fix'd the Rind O laid into the upper Stone PP, which it bears up and turns about. That upper Stone

PP. WHOSE Diam. is 5.8
Thickness at the Edge 0.5
Middle 1.4 } And between the Edge and the Middle the Convexity is about 1 Inch $\frac{1}{4}$.

Q. A Wallower 2.4 Diam. of 15 Rounds, which is at pleasure applied to the Cog-Wheel LL. On the same Axis is

R. A Cog-Wheel 5.4 Diam. of 40 Cogs, turning

S. A Wallower of 9 Rounds, whose Axis

T. HAS a Rind Y at its top bearing and turning the upper Mill-stone

W. WHICH Stones are used for grinding Wheat for fine Flower. They are 4 Feet Diam. $5\frac{1}{2}$ thick at the Edge, 15 in the Middle, with the Convexity between of $1\frac{1}{2}$.

X.

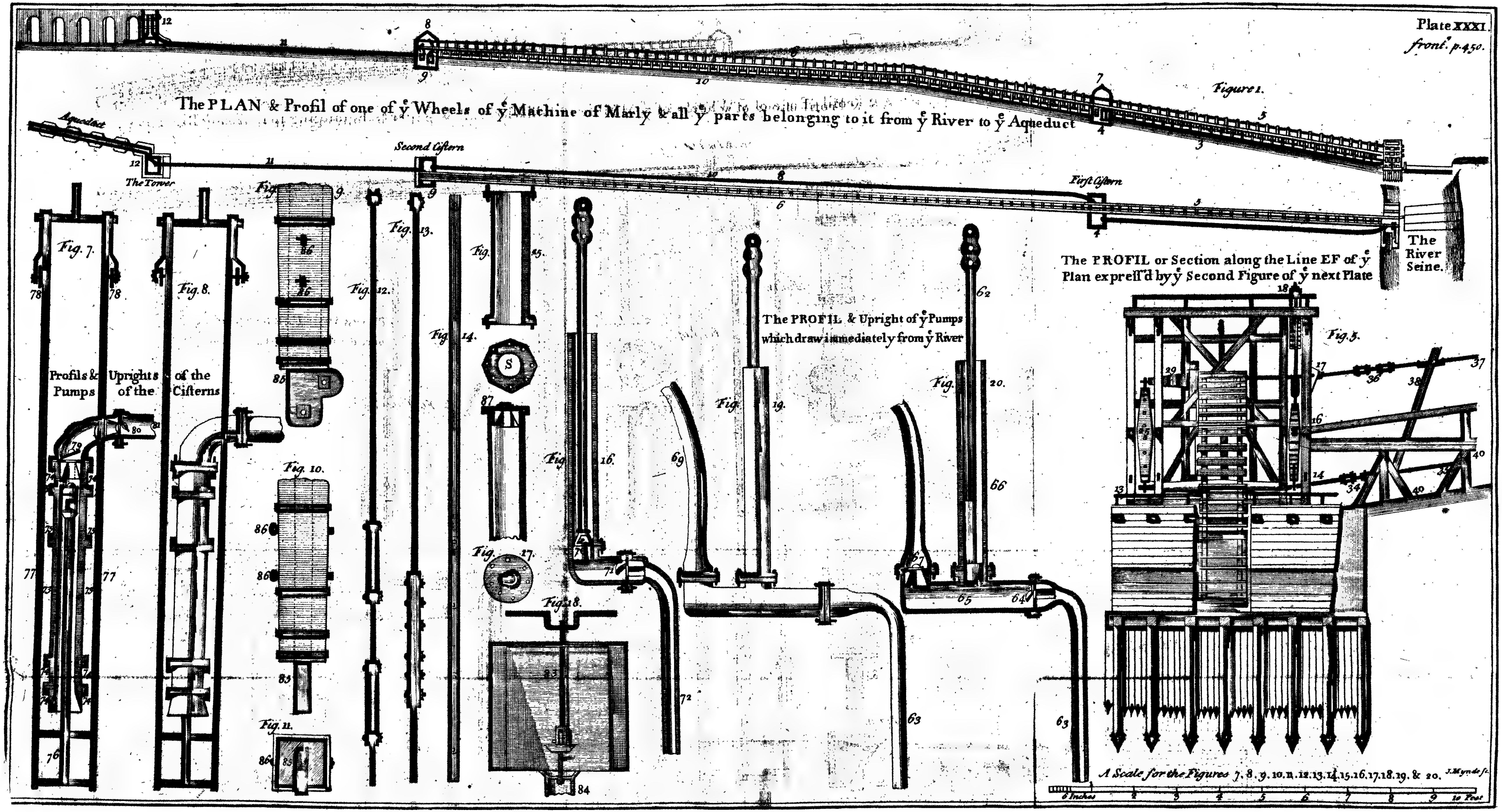


Plate XXXI.
front. p.450.
The PLAN & Profil of one of ye Wheels of ye Machine of Marly & all ye parts belonging to it from ye River to ye Aqueduct
Figure 1.
Aqueduct
The Tower
Second Cistern
First Cistern
The River Seine.
The PROFIL or Section along the Line EF of ye Plan express'd by ye Second Figure of ye next Plate
Profils & Uprights of the Pumps of the Cisterns
The PROFIL & Upright of ye Pumps which draw immediately from ye River
Fig. 7.
Fig. 8.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.
Fig. 16.
Fig. 17.
Fig. 18.
Fig. 19.
Fig. 20.
Fig. 3.
A Scale for the Figures 7. 8. 9. 10. 11. 12. 13. 14. 15. 16. 17. 18. 19. & 20.
6 Inches
10 Feet
J. Mynde sc.

X. THE Surface of the Water in the Pool lying $7\frac{1}{2}$ Feet above the Level of the Top of the Wheel.

Y Z. A TROUGH or Lander conveying the Water from the Pool at Y, and delivering it into the Buckets of the Wheel at Z. This Trough is 12 Inches ſquare within, having

a b. A Penſtock upon it, whoſe Cavity is the ſame, and

c d. AN Orifice $10\frac{1}{2}$ broad and 12 high, with a Shuttle or Sluice to open and ſhut it, which lets the Water upon the Wheel, and is (generally) raiſed about 2 Inches by means of

e. A LEVER or Balance fix'd to its Shank, by the Handle *f*.

THIS Mill will grind 30 Buſhels in 12 Hours.

THE Velocity of the $\left\{\begin{array}{ll}\text{Wheel} & 8 \\ \text{large Stone} & 40\end{array}\right\}$ *per* Minute.

BUT as it is Force, Power, Action, *&c.* that is moſt wanting to be known, and has as yet been but little conſidered; I ſhall here ſubjoin the *Calculus* in ſuch a plain manner, as may be underſtood by any who are a little vers'd in Numbers; tho' to have done the ſame in an Algebraic, or (ſome Parts) in a Fluxionary Proceſs, would have been more elegant, but not ſo generally underſtood and examin'd.

For the Velocity of the Water and the Wheel:

1. THE Water falls 7,5 Feet = 90 Inches, which Space a heavy Body falls in 41‴, and a double Column of Water iſſues forth, *viz.* 15 Feet. Then in one Minute there will be expended at the Orifice 1350 Feet = 16200 Inches; and the Opening of that Sluice being 10.5 × 2 = 21 Inches Area, there will be 1206 Ale Gallons fall on the Wheel in a Minute = 19 Hogſheads 9 Gallons, or 1148 Hogſheads *per* Hour.

2. THE Diameter of the Wheel being 16 Feet, the Circumference is 50,3 Feet;
Which multiplied by the Revolutions it makes in a Minute = 8
The Wheel goes in a Minute, or its Velocity is——————402,4 Feet.
Then as 402 : 1350 :: 1 : 3,35; ſo the Velocity of the Water to the Velocity of the Wheel is as 3,35 is to 1.

3. THE Adjutage, as above, gives 1206 Gallons, which divided by 8, gives 150,7 Ale Gallons, which ÷ by 30 the Number of Buckets gives 5,02 Gallons to each Bucket, that is nearly 50 lb. wt. of Water in each Bucket.

4. BUT as only one Bucket, *viz.* that horizontal with the Axis, can act by a Force of 50 lb. on the longer End of the Lever, the Radius of the Wheel E E (the ſhorter End being the Radius of the Cog-Wheel L L,)

Lect. XII. their Forces in proportion to their Centers of Gravity will be different; which calculated, and from thence their Statical Weights, (as I call them) their Forces will be (in a less Number than half the Buckets) as in the Margin. The Sum of the Weights in the last Column will be 3 hundred and 66 Pounds.

Buck.	*lb.*	*hund. lb.*	*Stat. Wt. lb.*
1	50	1.0	6.8
2	50	2.6	17.6
3	40	4.3	29.2
4	50	5.6	38
5	50	6.3	42.8
6	50	6.8	46.2
7	50	7.3	50.
8	50	7.2	49.5
9	42	6.8	38.
10	40	6.3	33
11	36	4.4	27
12	31	4.0	17
13	22	2.5	7

402,1=3 hun.66lb.

5. BUT as a cubic Inch of Water weighs 58 Ounces, and there is always falling 3780 cubic Inches, the Force impress'd, were it on the Tangent of the Wheel, will amount to 137 lb. but the Distance of the Penstock from the Pool 6 Feet. The Force is in it and by the Shuttle, as also its striking obliquely on the Paddles or Buckets nearly to an Angle of 45 Degrees; from which Considerations (and Experiments I have made) its Velocity, and consequently Force is lessen'd about one half: Therefore I add only 60 *lb.* to the Sum of Statical Weights, and it makes 4 Hund. 0 *q.* 14 *lb.* = 462 Pounds.

6. RAD. Wheel 8

Rad. Cog-Wheel 35)3696(1056 Force at the Cogs or Trundle of the Stone equal to 9 hund. 48 lb. for the Resistance of the Stones, the Grinding, and the great Friction of the Stones and Corn.

Or 1056

× by Rad. Wall. .75

Rad. of the Stone 2.8) 729(282,8 lb. Force at the Periphery of the Stone = 2 hund. 2 *q.* 2 lb.

7. THE Force on the Wheat-Mill Rounds (Q) 1056

The Rad. of that Wallower × 1.2

The Rad. of the next Cog-Wheel 2.4)1261,2(526lb. Force on the Trundle (S) that carries the Wheat-Mill, and 526 × Rad. Wall. 7 In. = 3682 ÷ 24 Rad. of the Stone gives 153lb. Force at the Periphery thereof.

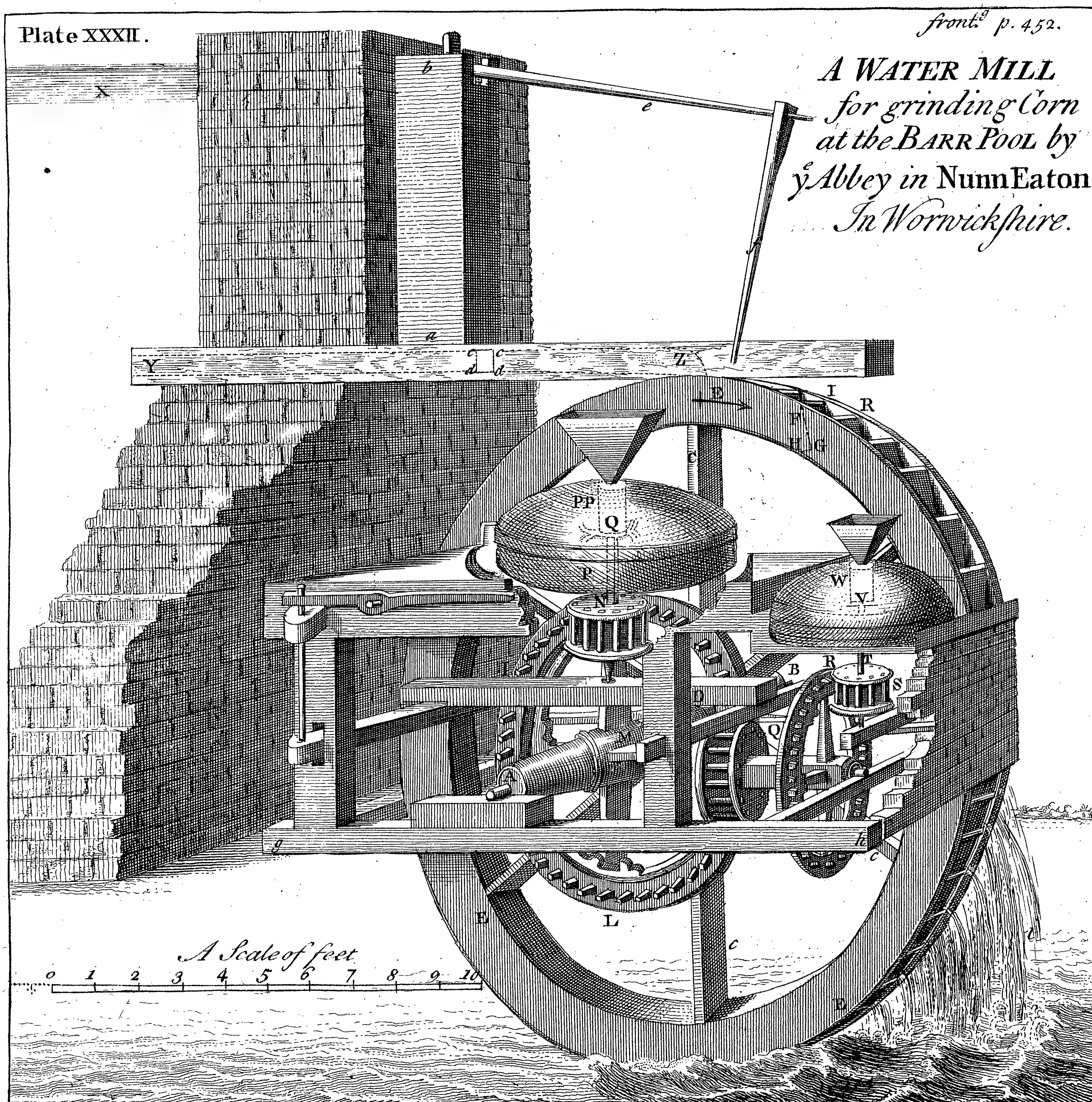
8. THE great Stone makes 5,33 Revolutions for the Wheels 1, and 42,4 Times *per* Minute.

Rounds, Cogs (3.2
15 48 (× 8 times the Wheel
25,6
9)40(4,4 × 4,4
112,6 *per* Min.

The Velocity of the Periphery of the great Stone.

Its Circumf. 3136
× 42.4
754,72 Feet in a Min.

Also the Velocity of the smaller is 1407,5 Feet *per* Min.



Hen. Beighton. F.R.S. delin 1723.

J. Mynde sc.

9. THE Weight of the Mill-stones.
The great one contains 22,5 cubic Feet = 1912 lb. = 17 hund. 0 *q.* 4 lb.

THIS Water-Mill is by most People accounted as good a one, as any the Country affords, for dispatching as much Business in the time, and doing it well; tho' perhaps amongst the Curious there may be some Objections against its Train (as the Movement-makers call it) for they generally say that the Pinion should divide the Wheel exactly, or be some aliquot Part of it, which here is not; for 9) 4.8 (5.33, but had it been

$$\begin{array}{r} 4.5 \\ \hline 40 \\ 27 \end{array}$$

9) 54 (6 it then had been such.
0

HOWEVER this goes well, it is a very agreeable Height 16 Feet, the Fall considerable $7\frac{1}{2}$ Feet; for the Wheel being made 20 Feet high in the Place it stands, it would not have been capable of doing so much business: Of so much more service is the Impulse, Stroke, or *Momentum* of the Water, than is its bare Statical Weight.

N. B. *Our Bushel here generally holds* $\frac{1}{32}$ *Parts more than the* Winchester.

A COMPARISON between this Mill, and the Undershot Mill that I have describ'd from Monf. *Belidor*, the Reader will find in the Notes *. * Ann. 5.

SECTION IX.

WHEN there is not a Quantity of Water sufficient to turn an Undershot Wheel, nor Height enough to throw the Water down upon an Overshot, the Water is made to fall into the Buckets of a Wheel call'd a Breast-Wheel, about the Height of the Center of the Shaft, and to work by its Weight till it goes down to the Bottom where it runs out of the Wheel: but few of these Wheels are good for any thing, because they seldom receive their Water well, and generally part with it too soon; that is, before it comes to the Bottom. But the learned and ingenious Dr. *Barker*, whose Skill in Mechanicks as well as all Parts of Mathematicks and Philosophy is well known, has contriv'd such an Improvement of this Wheel as to make it equal to an Overshot.

SIR *George Savile* had a Mill in *Lincolnshire* to grind Corn, which took up so much Water to work it, that it sunk his Ponds visibly; for which reason he could not have constant Work: but now by Dr. *Barker*'s Improvement, the waste Water only from Sir *George*'s Ponds keeps it constantly

Lect. XII. ſtantly to work. The Mill is improv'd in the following manner. *Plate* 33. *Fig.* 1.

Plate 33. Fig. 1.

This Wheel is 19 Foot in Diameter with 12 Arms and 24 Ladle-Boards; and is ſo contriv'd that the Ladle-Boards receive their Water a little above an horizontal Diameter of the Wheel, and do not part with it till they come to the loweſt Part of the Wheel under the Center, where the Water would not only be ineffectual, but hurtful to the Motion. The Contrivance to effect this is as follows: There is a circular Channel G ✓ G H, reaching from the Level of the Wheel's Center quite to its under Part exactly ſquare within; that is, the Section made thro' this Channel by a Plane paſſing thro' its Wheel's Center is every where a Square of 18 Inches the Side, as *g g* G G *g g* in *Fig*. 2. where the Section of the Wood that makes this Channel is ſhaded. The Ladle-Boards F F being 18 Inches long and 18 Inches broad, juſt paſs down this Channel without touching, and ſcarce loſe any Water at all (the little that ſlips by the firſt going to the ſecond) in going round a quarter of the Wheel, *viz.* from G to H, when they wholly quit the Water. To do this the more effectually, from the Middle of the Rim or Sole, quite round the Wheel there riſes a Tongue going all round, of about an Inch and a half or two Inches in Thickneſs, to fill up the Space between *g* and *g* in the ſquare Channel, and in order to ſupport the ſtrong Pieces on which the Ladle-Boards reſt. The third Figure at *b b a a a a a a b b* repreſents the Section of the Sole of the Wheel and this Tongue prominent upon it, and D *d* is the Supporter of the Ladle-Board thruſt thro' under it, with an Hole near *d* to drive a Key or Wedge on the Inſide of the Sole of the Wheel to hold faſt this Piece, over whoſe End *b* D *b* the Ladle-Board is to be faſten'd.

In *Figure* 2, *d a a* F D F *a a* repreſents the Section of the Sole of the Wheel and Tongue, with the Ladle-Board F F faſten'd over the End of the Supporter at D. N. B. *When the Ladle-Boards are faſten'd to their Supporter one may very eaſily and expeditiouſly put them into their Places, by thruſting the Part of the Supporter* d b b (*Fig.* 3.) *thro' the Tongue and Sole of the Wheel, and making it faſt with a Key at* K, *in the Place* 1, *a little before the Entrance into the Channel.*

Section X.

When we have not Water enough to turn ſuch a Mill as this, and even an Overſhot Mill; but can give a great Fall to the Water we have, we may make very good uſe of that Water, the ſmall Quantity of it being recompenſed by the Height of the Fall. Mr. *Francini*, in the Year 1668, was the firſt that I know of, who brought a great Fall of a little

little Water to be useful, and others have practis'd it since. I have taken this Account out of *Belidor*'s *Architecture Hydraulique*, Page 254, Vol. II. and give it here in his Words. Lect. XII.

FRANCINI'*s Pump.*

A PARTICULAR Sort of Chain, or Joint-Pump contriv'd by Mr. *Francini.* Plate 34. Fig. 1, 2.

THIS is the ingenious Machine contriv'd and put in execution by Mr. *Francini*, in the Year 1668, by Mr. *Colbert*'s Orders, in the Garden of the King's old Library. To judge of it well, you must know that near the House there is a natural Spring, which used formerly to discharge its Water in a Bason situated in the middle of the Garden, and that the waste Water used to run along a Canal into a Well, where it was lost. M. *Francini* taking advantage of the waste Water, and the Depth of the Well, rais'd an artificial Jet in the middle of the Garden, which produc'd a fine Effect.

THE first and second *Figures* of *Plate* 34. represent the Profil and Elevation of this Machine, compos'd of a couple of double endless Chains made of small Iron Bars join'd together by Joints or Hinges: to these are fasten'd Buckets making two Joint-Pumps of unequal Height, which turn upon a Rag-Wheel F E D G, that has Notches where the Chains go, to hold them always in the same Direction; and the Intervals of the Bars of this Wheel are equal to the Length of one of the Links of the Chain; that the great Joint-Pump turning with the Rag-Wheel, the other Joint-Pump may be forc'd to turn along with it.

THE Axis of the Rag-Wheel is sustain'd by two Posts P fram'd into Cills on the Curb at top of the Well, and so brought up to their Height, and kept fast by two cross Pieces Q R, the lowest of which sustains the Cistern A, which the waste Water of the Bason runs into.

THE Buckets B of the great Joint-Pump are made of Plates of Brass, making a Vessel wider at top than bottom, the better to receive the Water from the Cistern A, which runs continually through the Trough X; this Figure is so much the more convenient for these Buckets, that when one of them is full, the Surplus of the Water that runs along its Surface, runs naturally into the next Bucket below, and from that into the third, and so on, so that no Water can be lost by spilling over.

THE Buckets C and S of the lesser Joint-Pump, *Fig.* 2. have the same Figure as the others, with this Difference, *viz.* that they are clos'd all round, except at the Place S, where they have a little Neck towards the Bottom, where the Bucket is least, which Neck is upwards when the Buckets rise full of Water to discharge it into the upper Cistern

M I.

Lect. XII. M I. To make the thing plainer, we have drawn by themſelves, between *Fig.* 1. and *Fig.* 2. one Bucket of the great Joint-Pump, and one of the ſmall one, which ſhews the Situation in which they are, when being full of Water, thoſe of the great Pump deſcend into the Well, and thoſe of the ſmall one riſe to empty themſelves into the upper Ciſtern.

THO' the firſt Figure repreſents only one Joint-Pump ſeen ſide-wiſe, it may ſerve to ſhew the working of each in particular. For example, you may conſider the Buckets B, as thoſe of the great Pump, when they go down into the Well, and the others H of the ſame when they riſe empty. If on the contrary we conſider the ſmall Pump, you may judge of the Situation of its Buckets H, when they riſe full of Water, and of the Situation they have at B, when they come down empty.

A WHEEL with Teeth O has been fix'd to the Axis of the Rag-Wheel, whoſe Teeth take a Pinion or Lantern N, *Fig.* 1. and *Fig.* 2. that has a Fly to keep the Uniformity of the Motion of the Machine, that it may not go by Jerks, and not feel the ſmall Alterations that may be caus'd by Obſtacles met with in the way, *Fig.* 1.

As the great Joint-Pump is ſuppoſed to go down into the Well to a Depth ſomething greater than the Height to which the Water is to be rais'd above the Level of the Ground, there will always be a greater number of its Buckets that will go down full of Water, than there will be of the little Pump that will carry up theirs full to the Rag-Wheel; conſequently the Weight of the Water that deſcends being ſuperior to that which riſes, the great Pump will neceſſarily make the little one turn, whoſe Buckets will fill themſelves as they go thro' the Ciſtern A, which upon that account muſt have a certain Depth, that the Water may have time to fill them.

As to Velocity proper for this Machine, it can only be determin'd by Experience, by increaſing or diminiſhing the Number of the Buckets of the great Pump, to know how much the Power muſt be ſuperior to the Weight; which muſt alſo depend upon the Quantity of Water the Spring is able to give.

WHEN the Buckets of the great Pump are of the ſame Bigneſs as thoſe of the ſmall one, and the firſt Chain of Buckets is ſomething more than double the Length of the ſecond, ſomething leſs Water will riſe in the upper Ciſtern than is loſt in the Well; that is, there will be rais'd ſomething leſs than half of what the Spring affords. If you would have more than half rais'd, but to an Height leſs than the Fall, you muſt then make the Contents of the Buckets of the ſmall Pump greater than the Buckets of the other, *in a reciprocal Ratio of the Fall of the Water*,

to the Height to which it is rais'd: and on the contrary, when you would raiſe the Water to a greater Height than the Fall; you muſt make the Buckets of the ſmall Pump leſs than thoſe of the great one, again in the reciprocal Ratio of the Deſcent and the Riſe of the Water; then there will riſe leſs than what is loſt in the Well, in the reciprocal Ratio of the ſame Terms. Lect. XII. Plate 34. Fig. 2, 3.

YOU ſee that in the Caſe where *Francini* made uſe of this Machine, after the Water had been rais'd into the upper Ciſtern M I, it came down by a Conduit-Pipe, and went and play'd a Jet in the Baſon of the Garden, whence it came back into the Ciſtern A, and united again with that of the Spring, to help to play the two Joint-Pumps, ſo that by means of this Circulation, a Spring affording but little Water, rais'd without Interruption ſo great a Quantity of Water, that one might borrow a Part for other Uſes.

THE chief Difficulty here, is to have a Well deeper than the Fall, in a Soil where the Water can be loſt; unleſs you can find a lower Place to conduct the Water to from the Bottom of the Well.

Devonſhire and *Cornwall*, where there are a great many Mines of Copper and Tin, is a very mountainous Country, which gives an Opportunity in many Places to make Adits, (as they call them) or ſubterraneous Channels or Soughs from the Bottom of the Mine where the Miners are at work, to ſome Valley at a diſtance, a little lower at the Bottom of the Mountain, to carry off the Water from the Mine, which otherwiſe would drown them out from getting the Ore. Theſe Adits are ſometimes carried a Mile or two, and dug at a vaſt Expence, as of 2, 3, or 4000 Pounds, eſpecially where the Ground is rocky. And yet they find this much cheaper than to draw up the Water out of the Mine quite to the Top, when the Water runs in plenty, and the Mine is deep. Sometimes they can't find a Level near enough proper to carry to it an Adit from the Bottom: ſuppoſe the Mine be 50 Yards deep, and they can only find a Level 25 Yards above the Bottom; yet they find it worth while to make an Adit to ſave half the Height to which the Water is to be rais'd, thereby ſaving half the Expence, and delivering the Water into the Trough L Z, where it runs off under ground without bringing it up to the Graſs.

THE late Mr. *Coſtar*, (I believe without having heard of *Francini*'s Machine) conſidering that ſometimes from a ſmall Stream, and ſometimes from little Springs or Collections of Rain-Water, one might have a pretty deal of Water above Ground, tho' not a ſufficient Quantity to turn an Overſhot Wheel; thought that if a ſufficient Fall might be had, that Water might be made uſeful in raiſing the Water from the Bottom of the Mine to the Adit, and thereby ſave the Expence of Men and

Lect. XII. Horses used for that Purpose: The Fall to be had appear'd to him to be C L; that is, from the Grass or Mouth of the Pit down to the Adit, which here we'll suppose 25 Yards. Then he contriv'd to place a Rag-Wheel R R, with its Chain or Bucket-Pump at the Mouth of the Pit at C *c*, much after the manner of *Francini*, receiving the superior Waters brought into a Collection-Cistern W, thro' a Pipe A, leading it into the Buckets B, making them go the reverse way (because in the common Chain-Pump the Rag-Wheel carries the Buckets, but here the Buckets carry the Rag-Wheel) down as far as the Adit, into which they discharge themselves at *b b*; and there turning another Rag-Wheel *r r*, whose Axis works an Engine bringing the Water from the Bottom, which is also deliver'd into the Adit which carries away both the Waters to the Delivery at the Bottom of the Mountain at Z, which we suppose at a great distance from the Mine. Any kind of Engine may be work'd by this lower Rag-Wheel, whose Axis is H I; as for Example, a common Chain-Pump, like that at D, *Fig.* 2. by making the Rag-Wheel sufficiently deep; or Cranks, as I have represented it at G *g* in the Figure, working two Pump-Rods K K moving in the Barrels M M, and delivering their Water into the Trough leading to the Adit.

Plate 34. Fig. 3.

N. B. *There must be a Wheel fix'd to the Axis of the upper Rag-Wheel at* C, *to carry a Pinion or smaller Wheel* D, *having a Fly* E F, *in order to regulate the Motion of the whole Machine, and prevent Jerks.*

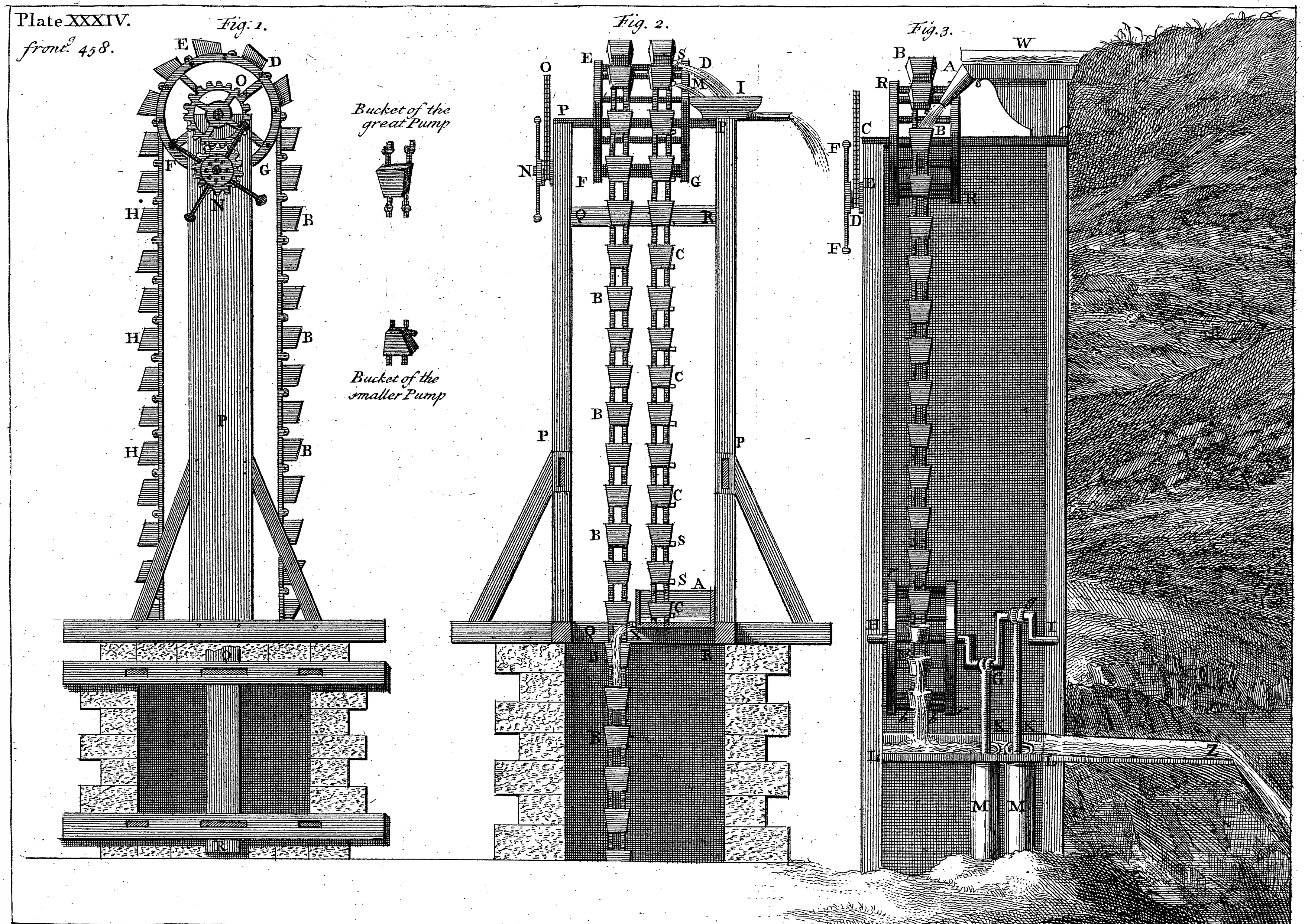
ONE may by means of an Adit, Sough or Drain, brought to any Depth in the Mine, make a considerable Advantage of a great Fall of a small Quantity of Water a great many ways. I have thought especially of two, which I will mention here.

1. THE first is to fix Dr. *Barker*'s Breast-Wheel a little above the Adit-Cistern under Ground, to which the Water must be led down by a perpendicular Pipe, whose Bottom ends in a strong, square, perpendicular Trunk, having a Mouth to open or shut by a Chain from above, so as to be let fall on the Ladles of the Wheel, and going out of the circular Channel at bottom of the Wheel, to fall into the Adit-Cistern, and there run off. The Axis of this Wheel in going round may move any kind of Water-work, to bring up the Water from the Bottom of the Mine into the Adit. See *Plate* 33. And inverting it, the Part mark'd *Fig.* 4. will shew the Application of the falling Water to the Wheel. P C P *p* is the Bottom of the descending Pipe conducted to the Mouth of the circular Channel G, where the Ladle-Boards run in the Direction 3, 4, 5, and quit the Water at 6. A Chain C O, pulling the Shuttle M *n*, lets down the Water upon the first Ladle-Board it can come at in proportion to its Quantity. The rest is very plain.

Plate 33.

Plate XXXIV.

front.[g] 458.



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2. If the Adit be very deep under Ground, (for Example, 50 Yards) the Velocity of the Water will be fuch, that the Channel of the Wheel G 3, 4, 5, 6, would not part with the Water foon enough for the Velocity of its Fall, therefore then there muft be no guiding Channel for the Ladles to go thro'; but they muft be fix'd like thofe of an Underfhot Wheel, and their Number muft be lefs than in Dr. *Barker*'s Wheel. Mr. *Pitot*'s Rule, given above, will fettle their Number, and the Stroke will be perpendicular againft every horizontal Ladle. *N. B.* The Velocity of the iffuing Water, fuppofing the Pipe to be kept full, will be found by our Rule of Page 422.

Here at 50 Yards it will be 80,2 Feet per Second.

For 150 Feet × 64,2882 gives 9643,2300.

Whofe Root $\sqrt{9643,2300}$ gives 80,2.

SECTION XI.

WHERE there is a Fall of Water not fufficient in Quantity to turn even an Overfhot Mill; fuppofing this Fall to be of 16, 20, or 30 Feet; it is poffible to make it turn a new invented Mill, the moft fimple that ever was made: without Wheel, Trundle, Cog or Round. Dr. *Barker* had this Thought, and communicated it to me, faying that it would be an experimental Proof of Mr. *Parent*'s Propofition, explain'd Page 424. of the Maximum of the Force of Water acting upon an Underfhot Wheel. I took the Doctor's Hint, and made the following working Model of it, which I fhew'd the Royal Society the Experiment of, at their laft Meeting this Summer.

The Defcription of a Machine to prove Mr. Parent'*s Propofition experimentally,* viz. *that an Underfhot Water-Mill does moft Work when the Water-Wheel moves with only a third Part of the natural Velocity of the Water that drives it.*

Plate 33.

FIGURE 5 reprefents an upright Section of the Machine, whofe Proportions are fhewn by a Scale of Inches.

A B C D is an upright Iron Frame ftanding on another Iron Frame for its Bafe, whofe Plan is reprefented by Figure 4.

E F G H I K is an upright Tin Pipe, with a Brafs fquare Pipe at bottom, turning round an Axis O N in the Direction E F, while two Jets fpout horizontally, but with different Directions, at the Sides of the

Lect. XII. Trunk I K near its Ends, as may be seen at Y, and suppos'd near K on the other side of the Trunk.

Plate 33. Fig. 5,6,7,8. Q the End of a Spout bringing Water into the Tin Pipe at the larger Part with a known Velocity.

N O a square Iron Bar so fix'd to the Tin Pipe as to make it turn round along with it, being join'd to it in the following manner, *viz.*

FIGURE 6, represents the Bar made round at top from R to O, in order to pass thro' the upper horizontal Bar in Figure 5, and going thro' the Cylinder P (which it does not touch by reason of the vertical Hole in P being larger than that Axis) sticks fast in the Barrel O, which it carries round to bring up upon occasion the Weight *a b* by a String over the Pulley B. At the Place W a Plate G H is let on upon the Bar, and fasten'd to it by the Pin W; which Plate by the Screws G H (*Fig.* 5.) is fasten'd to the broad Part of the Tin Tube: then the Bar running down the Tube, and thro' the Bottom of the Trunk at S, is fasten'd to it underneath by a Nut screw'd on at S, the remaining Part of the Bar being made into a Pivot S N, which passing thro' an Iron fix'd to the Bar C D, bears on a Piece of Brass T V fasten'd with Screws, or any otherwise to the under Part of the Iron. Thus when the Tube turns round, it carries the Bar with it, and the Roller or Barrel O.

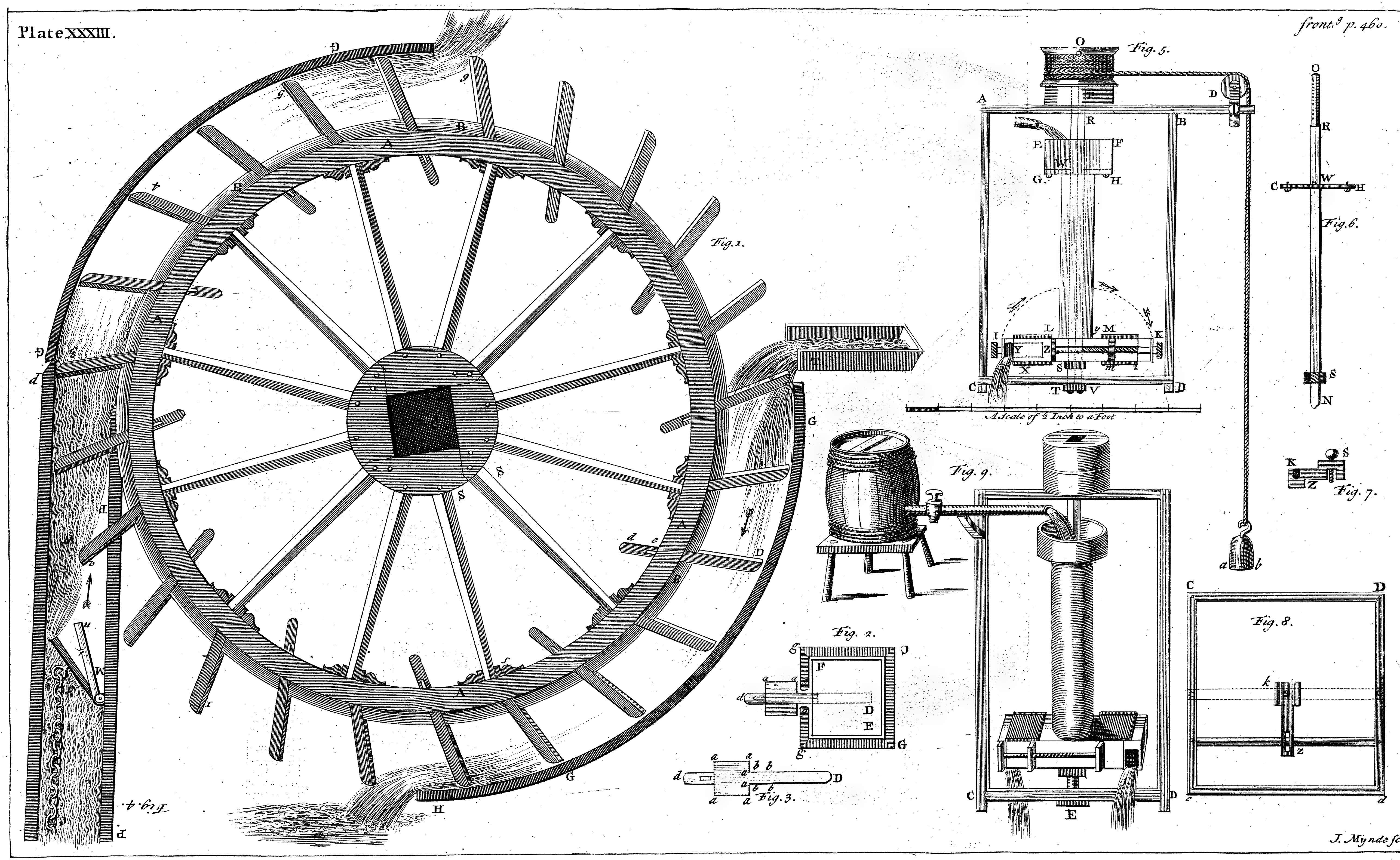
FIGURE 7, represents the Piece of Iron fasten'd to the cross horizontal Bar C D. T the Hole for the Pivot to go thro'; V the bearing Piece of Brass, and S the Screw to fix this Iron Arm to the Bar over N, where we have not represented it in the Figure 5, to avoid Confusion.

AT each End of the Trunk I K, on its opposite vertical Sides, is an Hole an Inch long, and $\frac{1}{4}$ of an Inch wide, mark'd Y Z, which may be open'd or contracted by means of a Plate of Brass L Y X Z, which slides over it, and is drawn backward and forward by the long Screw K Z, rivetted, but moveable round at Z, where the Plate returns at right Angles, and comes forward and backward, while the Screw advances and recedes thro' the Plate M *m*, which has a female Screw in it to keep the said Screw in its Place, while it preserves its Direction thro' another vertical Plate K at the opposite End of the Trunk; the Hole in that Plate not being screw'd. *N. B.* There is such another Plate and Screw, whose Head is mark'd I, to regulate the Hole on the other Side, and at the other End of the Trunk near K. *y z* represents the Place of that Plate; and L, X, M, *m*, four flat Plates with Dove-tail Grooves in them plac'd horizontally to guide the Shutter-Plates.

ALL this will appear in Perspective by the Sight of the ninth Figure. The Holes, such as Y, are to be open'd to make Jets, and to such a Bore, that as the Water comes out, the Ends I and K may move but with $\frac{1}{3}$ of the Velocity

Plate XXXIII.

front. p. 460.



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Velocity of the Water coming into the Pipe from Q: then the greatest Weight *a b* will be drawn up by the Roller O. Lect. XII.

IF you change the Scale from half an Inch to a Foot, this Machine will be a Mill (of little Cost) where O will be the upper, and P the nether Mill-stone. Plate 33. Fig. 8, 9.

FIGURE 8, is the Plan of the Frame of Iron at the Base, and AB the Plan of the cross Bar at top.

N. B. IN making a real Mill, the Mill-stones should be bigger than according to the Scale; for they should be 4 or 5 Foot in Diameter. The Piece CD, *Fig.* 9. must be made of springing Wood to make the Bar and Pipe, and consequently the upper Mill-stone at the Top of the Bar, dance a little in working, as has been shewn to be needful in Mills.

SECTION XII.

IF there be a Spring affording but a small Quantity of Water, and having but a small Fall, suppose 10 Foot, it is possible by the Loss of some of the Water to raise the rest to supply a Gentleman's Seat, or any Place where it is wanted; but in a less Quantity, by a little, than what runs waste, if the Place to which the Water is to be rais'd is higher than the Fall of the Spring is low. For example, the Fall of one Hogshead 10 Foot will raise very near a Hogshead 10 Foot: One Hogshead falling 10 Foot, will raise very near $\frac{1}{4}$ of an Hogshead 40 Foot. This has been thought of by *Schottus* a great many Years ago, and he gave a Draught of it; but I don't find that it was ever put in execution (at least to any good purpose) till the late *George Gerves* Carpenter erected an Engine for this purpose, for my honourable Friend Sir *John Chester* Baronet, at his Seat at *Chichester* in *Buckinghamshire*. This Engine has not been out of order since it was first set up, about 15 Years ago.

HERE follows the Description of it by Mr. *Beighton,* who also drew the Draught of it.

Plate 35. *The* EXPLANATION *of* Gerves's *Engine, set up for Sir* John Chester, *at* Chichester.

A. IS a small Spring of Water, running four Gallons *per* Minute, conveyed 72 Yards into B.

B. A CISTERN holding about 12 Gallons, with a Fall from B to C.

C. A CISTERN 10 Foot below B, where the Waste is convey'd off along D.

D. A DRAIN, or Sewer.

E. A PLAN of the Building by a Scale of 8 Feet in an Inch.

F G.

Lect. XII. FG. A SECTION of the Houſe built over the Well or Ciſtern, drawn by a Scale of 4 Feet in an Inch; with

HIK. THREE Floors, for the Conveniency of fixing and ordering the Engine; on the uppermoſt is

LMN. A FRAME of Timber, on which the moving Part is ſupported (Part broken off in the Figure, to ſhew the Work;) acroſs this Frame lies O,

O. AN Horizontal Axis, three Foot and an half long, moving on two Gudgeons in Braſſes. Upon this Axis are fram'd three Wheels.

(1) P. A WHEEL 2 Foot Diameter ſhrouded, whoſe Sole is 5 Inches broad, and ſhod with Iron.

(2) Q. THE largeſt Wheel 6 Foot Diameter, lying cloſe by the other, 1 Inch and $\frac{1}{2}$ broad on the Sole, and ſhrouded; this is ſpiral'd 2 Inches, both in Sole and Shrouds.

(3) R. A WHEEL 3 Foot 10 Inches Diameter, fix'd on the Sides of the Spokes of the Wheel Q, and ſhrouded; this is ſpiral'd $\frac{3}{4}$ of an Inch.

P. UPON the Wheel P, is fix'd a Chain, made flat and very flexible, which after it has wrap'd once round, is made double to ſtride on each Side the ſingle Part, to prevent its fretting and galling, and to keep exactly the Perpendicular.

SS. TO this Chain is hung SS, a long Rod of Iron, at the Bottom of which the greater Bucket (*d*) is fix'd.

Q. UPON the Wheel Q, is fix'd a ſmaller Chain made flat as the other; and when this Wheel has made one Revolution from left to right, the Spiral-Sole takes up as much of the Chain, as is between (T and T 2.) The lower Part of the Chain from (T 2 to T 3,) has croſs Bars, which fall upon the Edge of the Shroud in Notches plated with Iron; which, by the Help of the Spiral, not only prevent this Part of the Chain from riding upon the other, but help to equiponderate the Increaſe of Weight of the other Chain SS.

R. UPON the Wheel R, is faſten'd a Rope, one End of which goes about V,

V. A WHEEL of 2 Foot Diameter, to which that End is fix'd; and on the ſame Axis is fix'd W,

W. ANOTHER Wheel one Foot Diameter, to which is faſten'd a Rope, which goes over a Pulley to a ſliding Weight in a Box at X,

X. BEING the Stilyard End of (Y *aa.*)

Y *aa.* A QUADRANT Wheel moving on the Axis Y; the Rope falling upon Pullies, running betwixt Iron Plates, upon the Circumference.

Z. Is

Z. Is a Lead Weight, fix'd to counter-balance the Weight of the Chains, keeping exactly an *Æquilibrium* in every Position they move in.

O. Upon one End of the Axis O, is a strong Iron Wheel, giving Motion to a Fly (*b*) which regulates the Motion of the Engine.

T T. Upon one End of the Chain T T, is a Copper Bucket C; whose Capacity is about 5 Gallons, having a Valve in the Bottom on the left Hand, and a waste Pipe near the Top on the Right: Upon the lower End of the Rod S S, is hung (*d.*)

d. A Copper Bucket containing about 15 Gallons; in the Bottom of this is a Valve open'd by a Trigger falling upon a Stud at the Bottom of the Well.

i i. Are Iron Rods, for the guiding of the Buckets, whose Ears have Brass Rolls in them, and inclose 3 Sides of each Rod, which is square.

The Operation.

When the lesser Bucket descends, it falls upon a Trigger (at 4) which is jointed to a Treddle (at 5) express'd with pointed Lines, moving on an Axis (at 6), which by a Rod (at 7) opens a Valve in the Bottom of the Cistern B; whence the Water by a Brass Cock and Branch Pipe is conveyed underneath into both Buckets (*c* and *d.*)

When the lesser Bucket has received about 4 Gallons and $\frac{1}{2}$, it runs out at the Pipe or Spout into a Leaden Trough, which conveys the Water underneath the Cistern into the greater Bucket, till it overpoises the lesser, which descending, and raising the lesser Bucket, the Valve shuts, and the Water that is left in the Trough and Branch-Pipe runs into the greater Bucket (*d*) (accelerating the Motion) which falling 10 Feet, the lesser Bucket rises 30 Feet, which taking up the Trough (*f*,) and its Trigger striking upon a Stud at (*e*) its Valve is open'd and the Water runs out into a small Cistern at (*f*,) and down a Pipe (*g g*,) and so is convey'd to the Place design'd: At the same time a Stud opens the Valve of the greater Bucket, the Water running along D the Drain or Sewer.

When both Buckets are empty, the lesser overpoises the greater, and descends down to the Cistern, bringing up the greater, where they fill as before.

To regulate the Weight of the Chains in every Position, as they act in winding on and off the Wheels P and Q; the spiraling of the Wheels helps in some measure; but the Quadrant Wheel and Stilyard X, with the Weight Z, compleat that *Æquilibrium*, by acting with the greatest Force in the horizontal Position when the Chain T is all down, and acts with its whole Weight upon the Wheel Q. Then as that Chain is drawn up, its acting Weight being thereby diminish'd, the Stilyard X is moving down towards

Lect. XII. towards its Perpendicular, where the Weight Z ceases to influence the Motion of the Wheel R; at which time the sliding Weight runs down to keep the Rope tight.

AT the first moving down of the lesser Bucket, the Weight X slides up to a Shoulder before any Motion is given to the Stilyard; but whilst the Chain T evolves from its Wheel Q, its acting Weight increasing, and at the same time the Chain S wrapping it self upon the Wheel P, its acting Weight decreasing: The Stilyard by rising higher, brings the Line of Direction of the Weight Z farther from the Center of the Quadrant, and so lays a greater Force or Obstruction to retard the Wheel R; and continually keeps a Counter-balance.

THE Fly (*b*) regulates the Motion of the Engine to an equal Velocity; and by its running forwards, after the Buckets are quite up or down, holds them steady till they begin to fill or empty, and prevents their recoiling back.

THIS Engine at a slow Motion carries up one Bucket full in 5 Minutes; but if the Spring run double the Quantity, it would go up twice in the same time; and an Engine in this kind, may be made to raise one Hogshead *per* Minute, or more, if required; *The waste Water not being the hundredth Part of what is spent by a Water-Wheel, to raise an equal Quantity of Water to the same Height.*

HENRY BEIGHTON.

N. B. *There is mention'd in my First Volume (Page* 75, *and* 76.) *an Engine with a* losing *and a* gaining *Bucket, for the same purpose as this, set up in* Ireland; *but not near so good as this.*

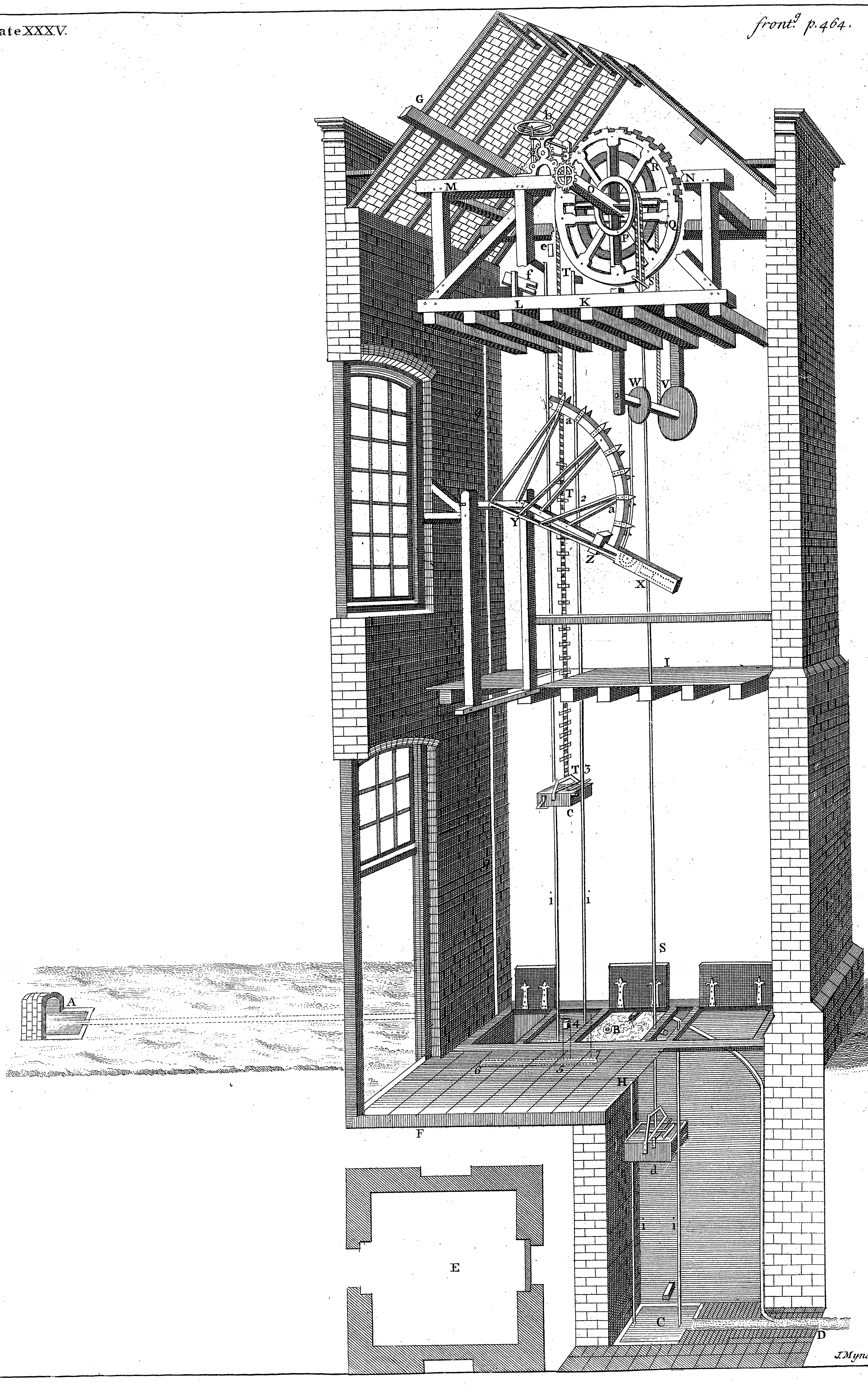
SECTION XIII.

FIRE-ENGINE.

WHEN Water is to be raised for supplying a Town or a Gentleman's House, or a Mine is to be drained of the Water which hinders the getting of the Ore; if there be a River, Brook, or Collection of Springs in our power, it is best to make use of an Undershot, Overshot, or Breast-Wheel; or of any Fall of Water, in *Costar*'s Way, or that which I mentioned in *Sect.* 12. of this Lecture, if there be a Drain to carry off the falling Water: because as such a Power costs nothing, there is no other Expence but setting up an Engine, and keeping it in order. But where there is no Water to be had, and Coals are cheap, the Engine now call'd the Fire-Engine, or the Engine to raise Water by Fire, is the best and

Plate XXXV.

front. p. 464.



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most effectual. But it is especially of immense Service (so as to be now of general use) in the Coal-Works, where the Power of the Fire is made from the Refuse of the Coals, which would not otherwise be sold.

It is now brought to very great Perfection; but it has been a long time in an improving Condition. I hope it will not be ungrateful to the Reader to have something of the History of it before we describe it.

SECTION XIV.

IN the latter End of King *Charles* the Second's Reign, the Marquis of *Worcester* published a Book, call'd, *A Century of Inventions*, (printed at *London* in the Year 1663,) which he describ'd, as having already put some of them in Execution, and proposing others as practicable and beneficial; for which he wanted Encouragement from the Legislature. Several were only Hints, and some Things he was mistaken in; but one of his Proposals in which he is most explicit, is that of raising Water by the Force of Fire, turning Water into Steam to press up great Quantities of cold Water. The Words of the Marquis, N° 68, are as follow:

'AN admirable and most forcible Way to drive up Water by Fire; not 'by drawing or sucking it upwards, for that must be as the Philosopher 'calleth it, *intra Sphæram Activitatis*, which is but at such a distance. 'But this Way hath no Bounder, if the Vessels be strong enough; for I 'have taken a Piece of a whole Cannon, whereof the End was burst, 'and fill'd it $\frac{3}{4}$ full of Water, stopping and screwing up the broken End, 'as also the Touch-Hole, and making a constant Fire under it; within '24 Hours it burst and made a great Crack: So that having a Way to 'make my Vessels, so that they are strengthened by the Force within 'them, and the one to fill after the other; I have seen the Water run 'like a constant Fountain-Stream, forty Foot high: One Vessel of Water 'rarefied by Fire, driveth up 40 of cold Water. And a Man that tends 'the Work, is but to turn two Cocks, that one Vessel of Water being 'consumed, another begins to force and refill with cold Water, and so 'successively; the Fire being tended and kept constant, which the self-'same Person may likewise abundantly perform in the interim between 'the Necessity of turning the said Cocks.'

CAPTAIN *Savery*, having read the Marquis of *Worcester*'s Book, was the first who put in practice the raising Water by Fire, which he proposed for the draining of Mines. His Engine is describ'd in *Harris*'s Lexicon, (see the Word *Engine*) which being compared with the Marquis of *Worcester*'s Description, will easily appear to have been taken from him; tho' Captain *Savery* denied it, and the better to conceal the matter, bought

 up

Lect. XII. up all the Marquis of *Worcester*'s Books that he could purchase in *Pater-Noster-Row*, and elsewhere, and burn'd 'em in the presence of the Gentleman his Friend, who told me this. He said that he found out the Power of Steam by chance, and invented the following Story to persuade People to believe it, *viz.* that having drank a Flask of *Florence* at a Tavern, and thrown the empty Flask upon the Fire, he call'd for a Bason of Water to wash his Hands, and perceiving that the little Wine left in the Flask had filled up the Flask with Steam, he took the Flask by the Neck and plunged the Mouth of it under the Surface of the Water in the Bason, and the Water of the Bason was immediately driven up into the Flask by the Pressure of the Air. Now he never made such an Experiment then, nor designedly afterwards, which I thus prove:

I made the Experiment purposely with about half a Glass of Wine left in a Flask, which I laid upon the Fire till it boil'd into Steam: then putting on a thick Glove to prevent the Neck of the Flask from burning me, I plung'd the Mouth of the Flask under the Water that fill'd a Bason; but the Pressure of the Atmosphere was so strong, that it beat the Flask out of my Hand with Violence, and threw it up to the Cieling. As this must also have happened to Captain *Savery*, if ever he had made the Experiment, he would not have fail'd to have told such a remarkable Incident, which would have embellish'd his Story.

Captain *Savery* made a great many Experiments to bring this Machine to Perfection, and did erect several, which rais'd Water very well for Gentlemen's Seats; but could not succeed for Mines, or supplying Towns, where the Water was to be raised very high and in great Quantities: for then the Steam requir'd being boil'd up to such a Strength, as to be ready to tear all the Vessels to pieces. The Heat, which is sufficient to boil Water, will produce Steam whose Spring is of the same Strength as common Air; but that Steam by the Removal of the Atmosphere and letting it return to press, is only capable of bringing the Water up to a little above 30 Foot; but for every 32 Foot that the Water is to be raised higher, the Steam must be so many times stronger than the Air: for example, if it is to be forced up 90 or 100 Foot higher than the Receivers, where the Steam acts upon it, the Steam must be three or four times stronger than the common Air; and a great deal stronger than that (perhaps six times stronger) upon the following Account: The hot Steam striking upon the Surface of cold Water in the Receivers, condenses itself, and thereby becomes uneffectual till the Surface of the Water and a small Depth of it, is warm enough not to condense any more Steam; and then (and not before) the Water yields to the Pressure of the Spring of the Steam to make it rise. I have known Captain *Savery*, at *York*-Buildings, make

make Steam eight or ten times ſtronger than common Air; and then its Heat was ſo great, that it would melt common ſoft Solder; and its Strength ſo great as to blow open ſeveral of the Joints of his Machine: ſo that he was forc'd to be at the Pains and Charge to have all his Joints ſolder'd with Spelter or hard Solder. Lect. XII.

THESE Diſcouragements ſtopp'd the Progreſs and Improvement of this Engine, till Mr. *Newcomen*, an Iron-monger, and *John Cawley*, a Glazier living at *Dartmouth*, brought it to the preſent Form in which it is now uſed, and has been near theſe 30 Years.

THO' his Method differs much from Captain *Savery*'s, and the Force of the Engine is quite different; yet it is wrought by the ſame Power, *viz.* the Expanſion of Water into Steam: and that Power is rais'd by Fire.

IN my Deſcription of this Machine I ſhall not follow the ſeveral Steps of the Improvement; but ſuppoſe the Reader quite ignorant of any ſuch Engine, and lead him as it were by Steps to the Knowledge of its Make and Uſe. Afterwards I ſhall ſhew that Captain *Savery*'s Method is not unuſeful in many Caſes; eſpecially when it is changed into the very ſimple Engine, that I have reduc'd it to, which I ſhall alſo deſcribe.

THE 36th *Plate* repreſents a few of the principal Parts of the Fire-Engine, which we will begin by, to lead the Reader gradually from the more ſimple to the moſt compos'd Parts of the Machine.

FROM a Well, Pit or Mine, as P, 50 Yards deep, is to be pump'd up the Water with a Pump whoſe Barrel is $7\frac{3}{4}$ Diameter; and therefore the Pillar of Water to be rais'd weighs (at a round Number) 3000 ℔. The Rod of the Pump is *i* faſten'd to the Chain *i* H, which hangs upon the remoteſt End of the Arch H *h* 2 9, fix'd to one of the Ends of a great Beam *h* 2 8 *h*, moveable upon the Center 8. Now if to the Chain H L, faſten'd to the other End of the Beam, be join'd an Hundred Ropes for as many Men to pull down in the Direction L *l*, they may bring down the End *h* of the Beam, and thereby raiſe up the contrary End of the Beam *h* 2, round whoſe Arch the Chain H *i* wrapping itſelf, the Piſton of the Pump and its Rod will be lifted up in the Direction P *p*, and a Quantity of Water proportionable to the Stroke will be lifted up, and run out at P. This may be done 15 or 16 times in a Minute, becauſe each Man would pull down but 30 Pounds at a time, after the manner that People ring Bells. But as no Time is to be loſt, leſt the Mine be overflow'd by the Springs below, there muſt be 100 more Men to relieve theſe when they are weary. Now as it muſt be a rich Mine indeed whoſe Profit can afford to keep 200 Men at this Work; Plate 36.

 that

Lect. XII. Plate 36. that Thought must be laid aside. We'll consider therefore what can be done by Horses. As an Horse is equal to five Men, we must work 20 Horses at a time to raise the Water requir'd; and as Horses must be reliev'd even more than Men, about 50 Horses must be kept to carry on this Work constantly, and bring down the End of the Beam *h*, 16 times in a Minute, and make the number of Strokes requir'd in the Pump, the Weight of whose Rod after every Stroke will bring down the End *h* 2, by drawing along the Tangent *i* H. It is plain to any body, that tho' the Horses may be had cheaper than Men, yet that will be a very expensive way. For the next Contrivance, we'll suppose a Philosopher to come, and find a means to bring down the End of the Beam, without Men or Horses, in this manner. To the Chain H L he fixes a Piston L C to go into a Brass Cylinder L C *d n*, about eight or nine Feet long, and 22 Inches Diameter on the Inside, where it is so smoothly bored, that the Piston C well leather'd may slip up and down without letting the Air pass by. We suppose this great Brass Cylinder to be fix'd in its Place, and to have a Pipe *d* D at bottom, with a Cock in it to open a Way into the Cylinder, or shut up the Passage at pleasure. Then we suppose the Philosopher to apply an Air-Pump at E, which being work'd some time will exhaust the Space C *d n* of the Cylinder under the Piston of all its Air. Then the Atmosphere, with a Column weighing about 5800 Pounds, will in the Direction L C press down the Piston C to *d n*, whereby the End *h* of the Beam will be pull'd down, the contrary End *h* 2 rais'd, and a Stroke (made equal to the Length that the Piston moves in the great Cylinder) to discharge Water by the Pump at P. The Cock being immediately turn'd at D, and the Air let in to the Vacuum of the great Cylinder, the Piston will be supported against the Pressure of the Atmosphere by the re-admitted Air, so as to have nothing but its own Weight to keep it down; but that Weight being much inferior to the Weight of the Rod of the Pump at the other End of the Beam, that End *h* 2 will fall again, and draw up the Piston towards L; from whence it may be brought down by a second Operation of the Air-Pump at E, and another Stroke of the Pump made. This would do very well if the Air could be exhausted fast enough; but the Cylinder cannot be evacuated above twice in an Hour, whereby we can have but two Strokes of the Pump, whereas we ought to have 960 in the same time; 16 Strokes in a Minute being requir'd to keep the Water in the Mine from overflowing the Works. But now an effectual Method has been found of making a Vacuum under the Piston C, 16 times in a Minute; and that is by using the Steam of boiling Water instead of Air, (for its Spring may be made as strong as that

of the Air) which performs as much as the Air in raiſing the Piſton C, and then is condens'd, and thereby remov'd, by a Jet of cold Water (ſo as to make a Vacuum) in leſs than two Seconds: and that is done in the following manner. Lect. XII.

A LARGE Boiler B of the Figure D *o o o o* A *o o o*, is fix'd under the Cylinder, and made to communicate with it by the Pipe E D *d*; a Steam-Cock or Regulator 10 E by a Plate at E ſlipping under the Pipe D *d*, or remov'd from thence by the Motion of the Handle 10, ſtops or opens the Communication from the Boiler to the Cylinder occaſionally. The Boiler being fill'd with Water up to S B *s*, a Fire is made at A, till the Water boils, raiſing on its Surface a Steam a little ſtronger than Air, but 16 or 17 times rarer. Then (the Piſton C being ſuppos'd at *d n*, kept there by the Preſſure of the Air) by puſhing the Handle 10 from 10 towards *n*, a Paſſage of about four Inches is open'd on a ſudden to let the Steam out of the Boiler into the Cylinder, where acting under the Piſton, it ſupports it as much as common Air would have done; and balancing the Preſſure of the Atmoſphere downwards upon the Piſton, gives liberty to the Pump-Rod, which hangs at the contrary End of the Beam, to go down to fetch a Stroke. Plate 36.

WHEN the Piſton is got up to C, or a little higher, by pulling back the Handle 10 towards O, the Plate of the Regulator E ſhuts up all Communication, ſo as to hinder any farther Reception of Steam into the Cylinder. Then muſt be lifted up the Leaver O *i*, (commonly call'd the F) ſo as to turn by its Teeth the Key of the Injection-Cock at N, which permitting the Water to come down the Pipe *g* M N, from the injecting Ciſtern *g*; a Jet of cold Water is made thro' *n* againſt the Bottom of the Piſton, from whence the Drops being ſcatter'd over the Cylinder, condenſe the Steam into Water again, making its Bulk 14000 leſs than it had when Steam, which makes a Vacuum ſufficient for the Preſſure of the Atmoſphere to act again unbalanc'd, and raiſe the other End of the Beam with its Pump, to diſcharge the Water at P. Now this Operation is perform'd in two Seconds, which is the ſame thing as if an Air-Pump could exhauſt the Air out of the Cylinder in that time. Shut the Injection-Cock, and open the Steam-Regulator to let the Steam meet the Piſton, before it is come down low enough to cruſh the Pipe *d*, and it will riſe again towards L, a Cup full of Water, (whoſe Uſe will be explain'd hereafter) from whence it will be brought down again by ſhutting the Steam-Regulator, and opening the Injection-Cock as before, &c. So that a Man alternately opening and ſhutting the Regulator 10 E, and the Injection-Cock N, may work this Engine 16 Strokes in a Minute.

THUS

Lect. XII. THUS is the Fire-Engine, in its present State, a very simple and plain Machine, where an immensely powerful Stroke for working of Pumps (for the Motion will be just as easy when the Area of the Cylinder is 10 times greater) is perform'd by only turning two Cocks alternately: and yet were a Person, who knows nothing of the Engine, to see it the first time, he would imagine it to be very complex by the number of Parts that offer themselves to view. But here we must distinguish between what performs the material Operations of the Engine, and what serves for Conveniency, and the just Regulation of the said Operations. For not above the 100th Part of the Power in this Engine, (being one of the Engines at *Griff* near *Coventry*, as it work'd above 20 Years ago) nor the 1000th Part in very large Fire-Engines, is employ'd to turn the Cocks, and regulate all the Motions, as we shall explain every Part by degrees; first upon this Scheme referr'd to now; and afterwards upon Schemes representing all the Parts of the Engine successively, and as they are seen all together.

1. FIRST, as we must always have Water in the Cistern *g* to inject into the Steam to condense it; there is an Arch fix'd to the Beam near *h* 2, to carry a Chain, and a small Pump Rod *k*, which draws Water from a small Cistern near the Mouth of the Pit, (which Cistern is supplied by some of the Water rais'd at P) and forces it up the Pipe *m m m*, to keep the injecting Cistern *g* always full.

2. IN the next place, as the Piston C, which moves up and down the Cylinder, ought to be Air-tight, a Ring of Leather, or a Piece of Match, which lies upon its Circumference next to the Inside of the Cylinder, must be kept moist, and swell'd with Water. This is supplied from the injecting Cistern by a small Pipe *z* always running down upon the Piston, but in a very small Quantity if the Work be well perform'd. L is a leaden Cup, whose Office is to hold the Water that lies on the Piston, lest it should flow over when the Piston rises to its greatest Height in the Cylinder, as W; at which time if the Cup is too full, the Water will run down the Pipe L V into the waste Well at Y.

3. THIRDLY, as the Water in the Boiler B must waste by degrees, as it is constantly producing Steam, and that Steam continually let out for working the Engine; there ought to be a constant Supply of the Water to boil. This is perform'd by means of the Pipe F *f* about three Feet long, going down a Foot under S, the Surface of the Water in the Boiler, with a Funnel F at top, always open, and supplied by the Pipe W with Water from the Top of the Piston, which has the Advantage of being always warm, thereby not so apt to check the boiling of the Water, as if it was quite cold.

4.

4. FOURTHLY, As the Boiler will be in danger of burning, if the Water boiling away too faſt, the Surface of the Water ſinks much below S s; and if it be fed too faſt, there will not be room above the Water to have a ſufficient Quantity of Steam gather'd; there are two Gage-Pipes in the Plate G, (which Plate opens occaſionally for a Man to go into the Boiler) one of which has its lower End above the Surface of the Water, and the other has its lower End within the Water: the Office of which Pipes is to ſhew whether the Surface of the Water be neither too high nor too low, but exactly at S s. Becauſe then, upon opening the Cock of the ſhort one, it will give only Steam; and the long one open'd will give only Water. But if both give Steam, the Water is too low in the Boiler; and if both give Water, the Surface is too high. By this means the feeding Cock at F from the Pipe V may be ſo much open'd, as to feed the Boiler neither too faſt nor too ſlow.

5. FIFTHLY, As cold Water is injected into the Cylinder at every Stroke, that Water might in time fill the Cylinder, and hinder the Operation of the Engine; there is a Pipe coming from the Bottom of the Cylinder *d* T Y, call'd the Eduction-Pipe, thro' which the Water that has been injected, comes down every time the Steam is let into the Cylinder. This Eduction-Pipe goes an Inch or two under Water in the waſte Well Y, and having its End turn'd up is ſhut with a Valve Y to keep out the Air from preſſing up into the Pipe, but allowing the injected Water coming the other way to be diſcharg'd: whereby the Cylinder is kept empty.

6. SIXTHLY, If the Man who turns the Regulator to E, and the Injection-Cock N, when the Piſton is coming down, opens the Regulator, and lets in the Steam too ſoon to raiſe the Piſton again, the Stroke will be ſhorter than it ought to be; and if he does not open the Regulator ſoon enough, the Piſton coming down with a prodigious Force will very probably ſtrike againſt the Throat-Pipe D *d*, at *d*, and cruſh it to pieces. Likewiſe, when the Regulator is open, the Steam going into the Cylinder, and the Piſton riſing, the Stroke will not have its full Length if the Steam is turn'd off, and the Injection of cold Water made too ſoon; and if it be made too late, the Steam may throw the Piſton quite out of the Cylinder at top at L. Now therefore to prevent all ſuch Accidents, the Improvers of this Engine have found out a Method to make the Engine itſelf open and ſhut the Regulator and Injection-Cock, at proper Times and Places. This is done by fixing another Arch to the great Beam towards *h*, from which by a Chain hangs a perpendicular working Beam or Plug, (of which you ſee Part at Q) which comes down quite thro' the Floor below the Bottom of the Cylinder,

 and is guided in passing thro' an Hole in the Floor, which it exactly fits. This working Plug having a Slit in it, and several Pins, gives Motion to several Leavers, which open and shut the Regulator and Injection-Cock at proper Times, as we shall shew in a further Description hereafter.

7. SEVENTHLY, Lest the Steam should grow too strong for the Boiler, and burst it, there is a Valve fix'd at *b*, with a perpendicular Wire standing up from it, to put Weights of Lead upon it, according to the Strength of Steam that you would have; that if the Steam is stronger than you want, it may lift up the Valve, and go out. This is commonly call'd the Puppet Clack.

8. EIGHTHLY, In Captain *Savery's* way of working, the Steam was forc'd to be made eight or ten times stronger than common Air, so that there was sometimes a Force of near 150 Pounds pushing outwards upon every square Inch of the inward Surface of his Boilers; which Force they could not sustain without being spherical, and considerably thick. But here the Steam is but a little stronger than Air; the Boiler is made hollow at bottom, and with Flanches, (see the Figure) the better to receive the Heat of the Fire, which needs not be greater than that which boils the Liquor in a Brew-house. Nay, the Top of the Boiler S D *s*, is commonly made of Lead, and very well bears all the Pressure of the Steam.

9. NINTHLY, The Steam is in a fluctuating Condition, sometimes stronger and sometimes weaker than common Air; but never $\frac{1}{10}$ stronger nor $\frac{1}{10}$ weaker, as I shall shew, and any one may deduce from observing the Engine work.

WHEN the Regulator at D is shut, all the Steam is contain'd in the Space S D *s*; and then, as Mr. *Beighton* found it, the Engine work'd well, when there was the Weight of one Pound on every square Inch of the Puppet Clack *b*, which shew'd the Steam to be $\frac{1}{15}$ Part stronger than the common Air. Now as the Height of the feeding Pipe from the Funnel F to the Surface of the Water S *s* is not three Feet high, (as $3\frac{1}{2}$ Feet of Water are equal to $\frac{1}{10}$ of the Pressure of the Atmosphere) if the Steam was $\frac{1}{10}$ stronger than Air, it would push the Water out at F; which since it does not do, it cannot be stronger than Air, even in this its greatest Confinement.

WHEN the Regulator is open, the Steam gives the Piston a Push on the under side, which raises it up a little way; then occupying more Space, the Steam comes to be a Balance only for the outward Air, and so only sustains the Piston; but the Over-weight of the Pump-Rods at the contrary End of the Beam *h* 2 draw up the Piston beyond C as far as W. The Steam then expanded so as to fill up all the Cylinder would not

not quite ſupport it if it was not for the Over-weight above-mention'd. Lect.XII. If this was not true, when the End b 2 is down as low as it is to go, and reſts upon the Beams that bear its Center, the Chain L H above the Plate 36. Piſton would grow ſlack, and the Piſton might ſometimes be puſh'd out of the Cylinder, which never happens.

AGAIN, when firſt the Steam is let into the Cylinder, the injected Water is puſh'd by it out at the Eduction-Pipe d T Y, and is all out of the Cylinder by that time that the Piſton is got up to C. If then the Steam was ſtronger than Air, it would, after the Water, blow out at Y, the Valve Y not being loaded, which it never does. Here it may be objected, that if the Steam be weaker than Air, how comes the Valve to open at all to let out the injected Water? To which we anſwer, that the Bottom of the Cylinder at d being at leaſt four Feet in perpendicular Height above Y, the Steam, when weakeſt (ſuppoſe by $\frac{1}{10}$) is aſſiſted in its Preſſure by a Column of Water d Y four Feet in perpendicular Height, and therefore equal to near $\frac{1}{4}$ of the Weight of the Atmoſphere: But $1 - \frac{1}{10} + \frac{1}{4}$ is equal to 1 and $\frac{15}{100}$, and therefore capable of lifting up the Valve Y, which is only kept down by 1 the Weight of the Atmoſphere, and its own Weight; that is, not the 50th Part of it. All the injected Water therefore goes down, and out at Y, till the Surface of it be come down to T, where it reſts, when the Height T Y is but equal in Preſſure to $\frac{1}{10}$ Part of the Weight of the Atmoſphere, which join'd to the Steam now weaken'd, makes it capable to preſs neither more nor leſs than the common Air.

10. TENTHLY, As there is Air in all the Water that is injected; and that Air cannot be taken out, or condens'd with the Steam by the Jet of cold Water coming in at n, the whole Operation would be diſturb'd, and only a very imperfect Vacuum made. But there is a Contrivance to get rid of that Air, which is done effectually, and it is thus.

WE are to remember that when Steam is become as ſtrong as Air, it is above 16 times rarer; ſo that it will precipitate in Air as Quickſilver would in Water. Therefore all the Air extricated from the injected Water lies at the Bottom of the Cylinder over the Surface of ſo much of the injected Water as is come down to d n. Now there is without the Cylinder at 4 a little Cup with a Valve, and from under the Valve a Pipe going laterally into the Cylinder above its Bottom, to receive the Air into the Cup, which at every opening of the Regulator is puſh'd out into the Cup, and blows out at its Valve, when the Steam firſt puſhes in with a Force ſtronger than Air, which drives out all the Air from the Cylinder. The Steam does not follow, becauſe being now become

Lect. XII. weaker than Air, as we have ſhewn, the external Air being ſtronger ſhuts the Clack at 4. N. B. *This is call'd the* Snifting Clack, *becauſe the Air makes a Noiſe every time it blows thro' it, like a Man ſnifting with a Cold.*

11. IF the Reader is not acquainted with the Hiſtory of the ſeveral Improvements of the Fire-Engine ſince Mr. *Newcomen* and Mr. *Cawley* firſt made it go with a Piſton, he will imagine that it muſt be owing to great Sagacity, and a thorough Knowledge of Philoſophy, that ſuch proper Remedies for the Inconveniencies and difficult Caſes mention'd were thought of: But here has been no ſuch thing; almoſt every Improvement has been owing to Chance, as I ſhall ſhew in the Notes *, where I ſhall give the Hiſtory of thoſe Improvements.

* Ann. 6.

IN the mean time, by help of other Figures, I ſhall go on with the Deſcription of the Engine in its preſent Form and Manner of working.

Plate 37.

12. THE working perpendicular Beam, Part of which was only repreſented in the laſt or 36th Plate, is here repreſented in the whole, with all its Contrivances for opening and ſhutting the Regulator and Injection-Cock, and mark'd Q Q. This Machinery is all contain'd within the Compaſs of the Letters D *d* C 6 P 5 4 1 Q N F E; but its Parts are drawn ſo ſmall here, that you muſt at the ſame time have before your Eyes the next Plate 38, which in its ſixth Figure has all the Machinery above-mention'd much larger, and in other Figures every Part by itſelf, which by this means we may fully explain.

BETWEEN two perpendicular Pieces of Wood on each Side of P, (in this 37th *Plate*) and mark'd A B in *Fig*. 6, of *Plate* 38. there is a ſquare Iron Axis A B, (particularly repreſented *Plate* 38. *Fig*. 1.) which has upon it four Iron Pieces ſubſervient to the turning of the Regulator, by ſhooting forward and drawing back the Fork faſten'd to the Handle of the Regulator, (*Plate* 37.) and mark'd Q O E L, (*Fig*. 6. *Plate* 38.) or by the Letters N O M, (*Plate* 38. *Fig*. 2.) There is a Slit in the perpendicular working Beam contriv'd in ſuch manner that its Pins work on the fore part, middle, and back part, to raiſe and depreſs the Leavers 5, 4, that move the Iron Axle-Tree above-mention'd as far about its Center as is neceſſary. But the Reader will conceive the Thing better by a View of the Pieces in *Plate* 38, and then be enabled fully to underſtand the ſame Things in *Plate* 37.

Plate 38. Fig 1. THE firſt Figure A B repreſents the Iron Axle-Tree already mention'd, and mark'd by the ſame Letters in *Fig*. 6. There is a Piece *c e* D E, call'd the Y, from its repreſenting that Letter by its two Shanks, only

hanging

hanging down in an inverted Order, with a Weight F to be ſlipp'd on upon its upper Part, where it is made faſt higher or lower, as is convenient, with a Key or Wedge. This Y being ſlipp'd on over the End B of the Iron Axle is made faſt by driving in a Key after it at *e*: then there is a ſort of a Stirrup I K I, with a long Pin L to be fix'd occaſionally into the Holes on each Side of K: this by its Hooks I I is hung upon the Axle at *i i*, then a Spanner or Handle G 4 is driven on upon the Axle from the other End, ſo as to come and be faſt at *g* at right Angles to the Y: then a ſhorter Leaver or Spanner at half right Angles to this, (that is, between the long Shank of the Y and G 4) is forc'd on to *h*, upon the Axle, where it is made faſt. All theſe Pieces, as they are fix'd together on the Axle, may be ſeen at Figure 6; where you may obſerve, that when the working Beam goes up, by a Pulley held in its Middle by the Pin *q*, it lifts up the Spanner H 5, which turns the Axle ſo far as to throw the Y with its Weight F from C to 6, in which Direction, after paſſing the Perpendicular, it would continue to move towards Q, if it was not ſtopp'd by a Strap of Leather fix'd to its Top at Œ, and made faſt at the Points *m n*, in ſuch manner as to allow the Y to vibrate about a quarter of a Circle in falling forwards and backwards after it has paſs'd the Perpendicular.

Lect. XII.

Plate 38. Fig. 6.

The ſecond Figure repreſents the horizontal Fork M O N to be join'd at its End O to the Spanner or Handle of the Regulator P *q* Q 10, there being ſeveral Holes in theſe Pieces, that any Part of the End O may be kept in any Part of the Slit in the Spanner, as may be requiſite for the better Motion of the two Pieces. This may be ſeen in Figure 6, where the other End of the Fork is faſten'd to the Bottom of the Stirrup at E K N L, by the long horizontal Pin L, ſo that the Fork may continue horizontal, as it is ſhot forward, and drawn back by the Strokes that E and D, the Shanks of the Y, make alternately on the fore part or back part of the Pin L, in order to puſh forward, or draw back the Spanner P 10, to ſhut or open the Regulator in the manner that ſhall be further explain'd: we will only take notice now, that there is an horizontal Piece *u l*, ſo plac'd, that the End 10 of the Spanner may bear upon it, and be ſupported, as it ſlides backward and forward.

The preſent Situation of the Machine, as now repreſented by this ſixth Figure of Plate 38, is as follows. The Regulator is open, as appears by its Plate T Y being remov'd from under the Communication or Throat-Pipe S S, that goes into the Cylinder. The Piſton is now up about the Place C W, at top of the Cylinder in Plate 37. conſequently the great Beam, and the working perpendicular Beam are now almoſt at their utmoſt Height: and the Pulley in the Slit of the working Beam on the Pin *q*, has ſo far rais'd the Spanner H 5, that the Weight or Head of the Y is

 brought

Lect. XII. brought so far from under *n*, as to be past the Perpendicular over the Axle; and being ready to fall over towards *m*, it will with a smart Blow of its Shank E strike the Pin L, and drawing the Fork O N horizontally towards the working Beam, will draw the End 10 of the Handle of the Regulator toward *l*, and thereby shut it, by slipping the Plate Y under the Pipe S S. The Engine in *Plate* 36. is in this very Condition; but in *Plate* 37 the Blow is already struck, and the Communication cut off; as may be known by observing that the Weight at the Head of the Y is got to 6, as far as the Strap P 6 (mark'd *n* 6 in the sixth *Fig.* of *Plate* 38.) will let it go.

13. But now, before we proceed, it will not be improper to give a full Description of the Regulator. See *Fig.* 3. of *Plate* 38.

A Cock of four Inches Water-way, big enough to let the Steam out of the Boiler into the Cylinder, would have so much Friction, if made tight, as to require a great Force to turn it, especially as it must open and shut 32 times in a Minute, therefore the Regulator has been contriv'd instead of it.

The Brass Plate R, which you see here at R R in *Fig.* 6, and at D E in *Plates* 36 and 37, and L in *Plate* 39, in the middle of the top of the Boiler, is cast with the Pipe S S S of four Inches Bore, and work'd smooth at its Hole under the Plate, that it may be closely stopp'd by another smooth Plate *y* Y *y* apply'd under it, (where the Pressure of the Steam will hold it the closer when shut.) There is also in the Plate R R, a short Pipe or conic Hole, smallest downwards, to receive the Piece V W X, which being ground into it can move round without letting Air or Steam pass by. There is a square Shank Z Z, which is put thro' this last Piece when it is let down into its Hole, and pinn'd tight to it at the upper Z. Then the Spanner of the Regulator being put on, and made fast at V and W, as may be plainly seen in *Fig.* 6. *Plate* 38. where the whole Regulator is put together. This Regulator opens very quick, and ten times easier than a Cock of the same Bore: and to help the whole, the Weight F of the Y, when it has pass'd the Perpendicular, falls with a good Force, which makes the Shank under it give a smart Stroke, either within the Fork or without, to drive the Fork, and draw the Handle of the Regulator contrary to the way that the Weight is falling: the Weight causing the Regulator to be shut when it tumbles towards it, and be open'd when it tumbles fromwards it.

14. When the Regulator is shut, the next thing is to open the Injection-Cock to make the Vacuum, and immediately to shut it when the Piston begins to come down, (for the Vacuum is made in a Second of Time) and this is explain'd by *Fig.* 4. of *Plate* 38.

d c represents by two prick'd Lines the Bottom of the Cylinder towards the Injection, and *n* the Adjutage of the injecting Pipe within the Cylinder; *a b* Part of the Pipe coming from the injecting Cistern, *c b* the Cock, and *e* the Key of the Cock that has a narrow, long, upright Hole instead of a round one, that it may be the sooner open'd. Upon the Top of this Key is fasten'd on a Quarter of a Wheel with Teeth *l*, to be turn'd by another Quarter of a Wheel *i* hanging down from the Axis *h g*, which is mov'd by the Leaver *h k*, commonly call'd the F: See the sixth Figure of this Plate, where they are working together, and you may see how the perpendicular Beam moves them, by its Pins.

THE Moment after the Regulator is shut, the Beam not immediately losing its Motion upwards, the Pin *s* on its Outside lifts up the End 1 of the F, *h k i*, and opens the Injection-Cock; and the Jet immediately making a Vacuum, the Beam begins to descend, and the Pin *r* (which you may put higher or lower) depressing the F, shuts the Injection-Cock: then the Beam continuing to descend, the Pulley *p*, pressing on the Handle G 4, throws back the Y, whose Shank D throws forward the Fork, and opens the Regulator to let in fresh Steam, in the manner already describ'd; which Steam is shut off, by shutting the Regulator till the Cock for Injection of cold Water is again open'd, &c.

N B. *There is a way of opening and shutting the Injection-Cock different from this with the Quarter Wheels; more used, and I think a great deal better; because it moves with a Jerk, which is the best way to overcome Friction.*

Plate 38. *Fig.* 7.

AT the Center *c* of the F, K *f* there is a double Piece H making an Angle, to take between its Claws the Spanner H G of the Key of the Cock, which it can turn sufficiently to open and shut the Water-way. At the short End of the F is fix'd a Weight W within half an Inch of the End. When the Injection should be shut, the End of the F at K is lodg'd upon a Notch of a Piece hanging down at K D. But when any Part of the Machinery coming from the Plug or working Beam pushes off the Piece K D, the End of the F, with its Weight W, falls down with Force upon the wooden Block B, where it remains till one of the Pins of the Plug pressing upon the End *f* of the F, lodges the contrary End and Weight W at D, thereby stopping the Injection, which is renew'd again next Stroke by the Removal of D, &c.

Plate

Plate 38. *Fig.* 8.

15. THE 8th Figure of this Plate ſhews how the Iron Rods of the Pumps in the Well are joined together. A B is one End of a ſquare Rod that has a Stud or ſhort cylindrick Piece, ſhorter than the Bar is thick, fixed to it at right Angles near its End B at 2, and an Hole at 1, the Rod being a little thinner at B than elſewhere. The End of another Rod C, has a ſhort Cylinder 1 to go into the Hole 1 of the other Bar abovementioned, and an Hole at 2 to take in the other Bar's ſhort Cylinder 2; when theſe Bars have their Ends laid upon one another, the little Cylinders are hid, and the Bars appear only to have a ſquare Swell as at F. Then taking the ſquare Iron Collar D put it over the Bars at G and drive it to F, where it will remain faſt; eſpecially becauſe E is the lower Part of the Rod, and the leaſt ſhake at F rather faſtens than looſens the ſquare Collar put on.

Plate 38. *Fig.* 9.

16. WHEN we are to bring up the Water from a great Depth, as here from 50 Yards, if we endeavour to do it at one Lift, we ſhall burſt the lower Pipes, unleſs they be of Iron, which will be coſtly; but Wood will ſerve very well, if we divide the Work into three Lifts, of 50 Foot each. The way to do this is to divide the Iron Rod that goes down into the Mine into three, and work three Pumps at once with two Ciſterns by the way, and the laſt at top as uſual. The firſt or loweſt Pump P O is made in the following Manner. O*o* is the ſucking Tree at the Bottom of the Pit, which has its ſucking Valve near *o*; *o p* is the Pump-Barrel of Braſs or Iron, in which the Bucket works; *p* the upper Tree or Tree of Delivery, thro' which the Water is brought up, and comes out at Z into the Ciſtern Z P Q; in the lower Part of which the ſecond Pump is placed to draw up the Water, which is raiſed thither into the ſecond Ciſtern S R 2.

THE Rod Z Z which draws Water from the Bottom is at W Y branch'd out into another Rod W Y kept aſunder from it by the little horizontal Croſs-Bar Z V, and ſo goes thro' R, the Tree of Delivery to work its Bucket in the Barrel *r*, to draw out the Water from 1 thro' the ſucking Tree Q in the manner above-mentioned. This ſecond Rod goes on upwards to W W, to join to the principal or firſt Rod from the Beam at V, from whence is branch'd out another Rod towards T, which going thro' the Tree of Delivery T plays its Bucket in the Pump-Barrel *t*, which is made faſt to the ſucking Tree *s* S of the laſt Lift ſtanding in the loweſt Place of the ſecond Ciſtern S 2.

THE

THE Bucket of this Pump (which is a fucking and lifting Pump, ufed at the Machine at *Griff*) together with the Valves in the Trees, is defcrib'd at Page 157, and 158, where I fpeak of Pumps; the feveral Parts defcrib'd being reprefented by the Figures 7, 8, 9, 10, 11, 12, 13, 14, 15, and 16, of *Plate* 14. Lect. XII.

THE particular Defcription of the Pump-Barrels and bored Trees come next.

Plate 38. *Fig.* 10, 11, and 12.

THE 10th Figure reprefents a Cylinder of caft Iron or Brafs, here of $7\frac{3}{4}$ Inches Diameter in the Infide, of about 9 Feet in Length, very fmoothly bored from P to O, with Trunnions RR like a Cannon for the better Management of it, with a Shoulder at 3 and Q, and taper at the Ends from Q to P, and from S to O; in order to drive the lower End into the fucking Tree (*Fig.* 11.) at LB, where it is fecured by an Iron Hoop driven into the End of the Tree, as is fhewn by the prick'd Circle, the whole Bore of the Tree below it being alfo fhewn by prick'd Lines on each Side of N and O. HH is a fquare Hoop of Iron the better to fecure the fucking Tree, either when the Pump-Barrel is driven into it, or the fquare Plug KI, which ftops a fquare Hole to come at the fucking Valve which is fix'd at the Height of HH. *N. B.* When this Plug is in, it is fecur'd in its Place by Iron Bars and Screws. In the Bottom of the fucking Tree is driven a fhort Iron Pipe full of Holes C 3 O, to prevent Dirt and Coals from coming up with the Water; and a ftrong Iron Hoop AG is afterwards driven on upon the lower End of the Pipe, to keep all tight. When the Pump-Barrel P Q R R S O ftands faft upon the fucking Tree at LL, the lifting Tree ZWXTVY, of *Fig.* 12. (fometimes called the forcing Tree) is at its Mouth VT driven on upon the taper End OP of the Pump-Barrel, being alfo fecur'd by an Iron Hoop between V and T, and another eight-fquare one at Y. Thro' this Tree is let down the Bucket and Rod from above; the Bucket quite into the Pump-Barrel. And if the Bucket fhould at any time be foul, it is drawn up into this Tree between VT and YX, whilft a Man goes down into the Well, and cleans it by taking out the Plug at X.

Now we come to confider the Houfe in which the Machine ftands, and the particular Make of the Boiler and Cylinder, and the Manner of fetting the firft in Brick-Work, and making faft the laft in the Middle of the Houfe.

Plate 39. *Fig.* 1.

THE firft Figure reprefents the Place of the Machine. EBCD is the Plan of the Walls of the Houfe. *fff* the Plan of the Boiler; *c* that of

Lect. XII. of the Cylinder; *a b*, *a b*, that of the Beams that support the Cylinder, and of the Beams between which the great Beam plays. *c d* the great Beam, whose one End is at *c* over the Cylinder, and the other over the Pit at *d*.

Fig. 2.

THE second Figure represents the Upright of the four Walls of the House, of which CD and EB are suppos'd to be opposite to each other, the Doors and Windows being in those Walls. The two DE and BC are also opposite. The Wall DE has in it an Arch *m b n k*, under which the Boiler is fix'd, and the Chimney of the Furnace is mark'd in prick'd Lines. Here are four Holes *a a*, *a a*, the uppermost of which receive the Ends of the upper Beams between which the great Beam plays; and the two lower Holes receive the Ends of those Beams to which the Cylinder is made fast. See *Plate* 37. In the other Wall, BC *b b* represent the Holes in the Brick-Work for the other Ends of the Beams that support the Cylinder, and at *g* is the Window where the End of the Cylinder goes out; its Center-Pin or Gudgeons playing upon Brasses in the two Pieces over *a a*. The way of the Pipe feeding the Cistern of Injection is here mark'd in prick'd Lines. Hereunder is a Scale of Feet for the Engine-House at *Griff* here represented.

Fig. 3.

THE third Figure represents the Section Plan or horizontal Section of the Brick-Work under the Boiler. *a b b* is the Front of the Brick-Work, with the Door of the Fire-Place in its Middle. *b d c d* are the Bars upon which the Coals are laid. The Fire spreading over the Space *b d e d c* goes into the Flue at *e*, and so round the Boiler in the Channel *f g h*, and so up into the Chimney. *N. B.* It is observed that the little Passage between *d* and *d* from the large Fire into the Flue is of great use in quickening the Draught.

Fig. 4.

THE fourth Figure shews the upright or vertical Section of the Boiler and Brick-Work, (see *Plate* 36, and 37.) where all round the Bottom *o o* and under the Flanches *r s* from *o* to *s* the Fire coming from *n* is carried obliquely upward round the Boiler. Between *k* and *i* is the Strength of the Brick-Work, at *q* the Surface of the Water, at *l* the Steam-Pipe, and the Ash-Hole at *m*.

Fig. 5.

THE fifth Figure shews the Manner of joining together and riveting the Iron Plates of Mr. *Parrot*'s Invention, which lasts much longer and costs

costs five times less than the Copper Boilers. *u u u* is the Bottom, and *u w x y* shew how the Sides rise to make the Flanches. Lect. XII. Plate 39.

THE 6th, 7th, and 8th Figures represent the Cylinder and the Top of the Boiler. Fig. 6, 7, 8.

THE sixth Figure B A C D represents the Section of the Cylinder cast and bored. *a b* its first Flanch smooth at top to bear against a Floor or Beams, and keep the Cylinder from being push'd upwards. *d c* a strong Flanch in the Middle, to keep the Cylinder from going down, with Pieces standing out at *s*, *e*, and (see *Fig*. 8.) to make it fast to its supporting Beams. There is another Flanch at bottom at D C, with Holes all round to receive Screw Pins to fasten on the Bottom, represented in Section of *Figure* 7. where *l* G is the Throat-Pipe, whose Bottom has also a Flanch to join it to such another in the Top of the Pipe of the Regulator Plate, which is seen in *Fig*. 3. and *Fig*. 6. of the 38th Plate. The 8th Figure is the Cylinder in Perspective, look'd at from below, to shew the several Parts of the Bottom and of the Cylinder on its under Side, while *h h* shew the Screws and Nuts on the upper Side which hold it to the Cylinder, to whose Bottom it is made tight with a Ring of Lead between. E is a Pipe that leads to the snifting Clack. F leads to the Eduction Pipe, and G to the Boiler. H is a new Improvement for the better feeding of the Boiler, in the following manner.

16. IT had been found of benefit to feed the Boiler with warm Water coming from the Top of the Piston rather than cold Water, which would too much check the boiling, and cause more Fire to be needful. But after the Engine had been placed some Years, some Persons concerned about an Engine observing that the injected Water as it came out of the Eduction Pipe was scalding hot, when the Water coming from the top of the Piston was but just luke-warm, thought it would be of great advantage to feed from the Eduction or injected Water, and accordingly did it in the following manner, which gave a stroke or two of advantage to the Engine.

TO a short Pipe under the Bottom of the Cylinder *Fig*. 8. he join'd the Leaden Pipe H, something more than a Foot long, turn'd up at I, with a Valve on I, to be loaded with about 2 Pounds upon an Inch. Just under the Valve he carried a Communication into the feeding Pipe I *i*, so that the Boiler was fed at every Injection of the Steam. Plate 39. Fig. 8.

HERE a Philosopher may ask, how the Steam (which must be as strong, if not stronger, upon the Surface of the Water in the Boiler, as upon the Surface of the injected Water that lies at the Bottom of the Cylinder;) will yield so as to allow any Water to come into the Boiler thro' the feeding Pipe, by the Pressure of the Steam in the Cylinder? To which may be

Lect. XII. answered, that if the Steam upon both these Surfaces presses equally as Steam, we must add to its Pressure on the Eduction-Water the Height
Plate 39. Fig. 8. of a Column of Water *b* H, together with the Height in the feeding Pipe from I to the Surface of the Water in the Boiler; and then we have sufficient Force to feed the Boiler.

17. To judge of the Power of this Engine, we must consider what is the Weight of the Pillar of the Atmosphere that presses on the Piston, which is always proportionable to the Square of the Diameter of the Cylinder. Mr. *Newcomen*'s way of finding it was this: From the Diameter squar'd he cut off the last Figure, calling the Figure on the left hand long Hundreds, and writing a Cypher on the right Hand, call'd the Number on that side, Pounds; and this he reckon'd pretty exact at a Mean, or rather when the Barometer stood at 30, and the Air was heavy. N. B. *This makes between* 11 *and* 12 *Pounds upon every superficial round Inch.* Then he allow'd between $\frac{1}{3}$ and $\frac{1}{4}$ Part for what is lost in the Friction of the several Parts and for Accidents: and this will agree pretty well with the Work at *Griff* Engine, there being lifted at every Stroke between $\frac{2}{3}$ and $\frac{3}{4}$ of the Weight of the atmospherical Column pressing on the Piston. We'll give the thing in round Numbers.

DIAMETER of the Cylinder = 22 Inches; this squar'd is 484. Cut off the last Figure, and you have 48 hundred.

THE Pillar of Water weighs about 27 hundred, to which adding the Weight of 73 Yards of Iron Rods, *viz.* about 9 hundred, the Weight lifted
Plate 36, & 37. at the End of the Beam *b* 2 would be 36 hundred. *Plate* 36, and 37.

FROM which we must substract about 4 hundred for the Piston and Weight at the other End of the Beam *b*; reducing it to 32 hundred.

SO that the Weight of the Atmosphere 48 hundred, works with ease a Weight of 32 hundred with a Velocity of 6 Foot in 2 Seconds; for we only consider the rising Stroke.

THIS Engine at a Coal-Mine at *Griff*, from whence the Draught was taken, did discharge as much Water as did before employ more than 50 Horses, at an Expence not less than 900 *l.* a Year; whereas the Fire in Coals, Attendance, and Repairs, did never cost more than 150 *l.* a Year in this Engine.

Plate 39. *Fig.* 13.

Plate 39. Fig. 13. THE 13th Figure represents the Piston made of a thick Brass Plate with an Iron Shank DB going thro' its Middle, and fasten'd underneath by a Nut, or a Key, and made Air-tight there. To make it Air-tight round its Circumference CA next to the Cylinder, a long narrow Piece of Leather like an Horse-Bridle *e e* is turn'd round, so as to have its Edge next to the Sides of the Cylinder on the outer Side of the Holes or Pins

Pins Mark near C and A. To keep the Leather from quitting the Sides of the Cylinder, and contracting it ſelf towards E, 4 or 5 Pieces of Lead, flat and circular, with their Ends turn'd up as G F, are ſet upon the Piſton-Plate, ſo as juſt to touch the Leather on the Inſide, which they ſhove outwards in the working of the Piſton, being looſely join'd to one another by ſmall Pins at F, ſo as all together to make a Circumference of a Circle eaſy to dilate or contract, to preſs againſt or yield to the Leather, as the Piſton goes up and down. *N. B.* Sometimes only a long Piece of Match, or a ſoft Rope well ſoak'd keeps the Piſton tight inſtead of Leather.

The Operation, or Manner of firſt ſetting the Fire-Engine *to work. Plate* 38. *Fig.* 6. & *Plate* 37.

BEFORE you truſt the riſing and falling Beam (or working Plug) to turn the Cocks and regulate the going of the Engine by its Pins and Pulleys, your Labourer who looks after the Engine ſets it going in the following manner: The Pins and Pulleys being all ready for the Plug, but not fix'd into it till he has found the proper Places for them, the Regulator being ſhut, he obſerves when the Steam riſing from the boiling Water is ſtrong enough to raiſe the Puppet-Clack a little; then with his right Hand taking hold of the Handle 4 of the Spanner 4 G, depreſſes it, which turns the Axis AB part of a Turn, and thereby brings over the Y towards *n*, whoſe Shank D ſtriking the Pin L ſmartly, ſhoots forward the Fork to puſh on the Spanner of the Regulator, and open it. The Steam immediately going into the Cylinder, the Piſton riſes, and with it the great Beam. When the Piſton is up at its full Height as CW, (*Plate* 37.) the Operator, (tho' out of ſight of it) knows it by ſome Mark upon the Plug QQ, which is ſtill riſing, and raiſing the Handle 4, throws over the Y towards *m* and ſhuts the Regulator; but marks with Chalk about 5 the Place of a Pin and Pulley, which by its riſing will next time throw over the Leaver 5 H which is in its Slit, and by giving about a quarter of a Turn to the Axis AB, will next time throw back the Y towards *m*, and ſhut the Regulator. Then the Operator having hold of the End 1, of the F, *hi*, lifts it up, (marking the Plug at S to put in the Pin *s*) and opens the Injection, which makes a Vacuum in about one Second of Time. Then he ſhuts the Injection, which has done its Office; and the Piſton comes down very faſt, which (by opening the Regulator) he meets with the Steam, that drives it up again. *N.B.* You may ſee in *Plate* 37, that there is a ſtrong Frame F 1, F 2, upon which fall two ſtrong wooden Springs S 1, S 2, that if the Arch of the Leaver ſhould come down too low, there may be done no miſchief by the Piſton, and the whole Stroke may be made upon S 1, S 2,

 by

Lect. XII. by the ſtrong Iron Pin P 1, P 2, which will there be ſtopped. But when the Labourer has fix'd all his Pins right in the Plug or working Beam, the great Beam will move ſo regularly, as to come very near the Springs, and not touch them once in an hundred times. Then the Engine works it ſelf wholly, and the Operator is only to take care of the Fire, and ſee that no Accident happen. In the Coal Countries, when the Men go to dine and drink, they often leave the Engine by it ſelf for 3 or 4 Hours. So much is this Engine under Command, that I have ſeen a Fire-Engine whoſe Piſton came down with a Force of 20000 Pounds every time, ſtopp'd all at once by an Hair, ſtretch'd over and puſhing upon the End of the F, to keep it from injecting.

AND now I have done with the Fire-Engine, (as it works at all the Mines where it is uſed,) with a Leaver; except ſome few Things, which I ſhall mention in the Notes *.

* Ann. 7.

NOW to ſhew that Captain *Savery*'s Method is not wholly uſeleſs, I'll give an account of ſome Improvements I have made in it, and ſhew in what caſes it is more uſeful than the Leaver-Engine. But firſt to ſhew that Fire can give a much greater Force to Water turn'd into Steam than is uſually imagined, I will give the Experiment of the Burſt of Bubbles half full of Water, commonly call'd Candle-Granades.

Plate 39. *Fig.* 14.

Fig. 39. Fig. 14.

TAKE a little Glaſs Bubble G, of about the Bigneſs of a Pea, with a Stem half an Inch long, hermetically ſeal'd at the End, and full of Water. Stick it in the Tallow of a lighted Candle A, and puſh the Ball near the Flame of the Candle. If there be no Water at all in the Bubble, when the Candle burns down to it, it will heat red-hot, and the Air expanding with a ſmall Noiſe will burſt the Glaſs, as at B; blowing againſt it, and but ſeldom putting it out. But if there be Water in the Bubble, it will fly all to pieces with an Exploſion almoſt as loud as a Piſtol, when ſufficiently heated: and the Snuff of the Candle will be beaten down as if ſtruck with an Hammer, and the Fibres ſtretch'd out every way.

SECTION XV.

THE late Dr. *s'Graveſande*, before he was Profeſſor, came to *England* Secretary to the *Dutch* Embaſſy in the Year 1716, and then did me the honour to go thro' a Courſe of Experimental Philoſophy with me. As we were conſidering *Savery*'s Fire-Engine, as it is deſcrib'd in D. *Harris*'s *Lexicon Technicum*, we thought there was a great waſte

of Steam by continually acting upon the Receivers without Intermiſſion, it becoming uſeleſs till it had heated the Surface of the Water in the Receivers, and alſo to a certain Depth: and that if it were ſo contriv'd, that after the Steam had preſs'd up one Receiver full of Water, inſtead of being thrown upon another it ſhould be confin'd in the Boiler till the Receiver was refill'd by the Atmoſphere, and then turn'd upon the Water: That by this means its Confinement might give it ſo much Force, that it would puſh hard againſt the Surface of the Water, and have diſcharg'd a great deal of it, even before it had heated the Surface; and that *Savery* perhaps had, in his great Work *, choſen to uſe two Receivers, becauſe the Marquis of *Worceſter* mentions two in his Account: we reſolved to have a working Model made, to work either with one or with two Receivers. This Model ſoon ſhew'd us that one Receiver could be emptied three times, whilſt two ſucceeding ones could be emptied but once apiece. So that by this means an Engine would be ſo ſimple, as to be more eaſily work'd, coſt almoſt half leſs, and raiſe a third more Water. Accordingly I erected an Engine in the Manner ſhewn in *Plate* 40, whoſe Deſcription compar'd with the Draught in *Harris*'s Lexicon will ſhew my Improvements. Lect. XII.

EXPLANATION *of the Plate.*

A. THE Receiver, of Copper, communicating at bottom with the ſucking and forcing Pipes between F and G, and at top with the Steam-Pipe at D, and the injecting Pipe at I. Plate 40.

B. THE Boiler, of Copper alſo, containing at leaſt five times more than the Receiver, round which the Fire and Flame are conducted at T, T, T, T. It has a Copper Cover ſkrew'd on, which contains C D, the Steam-Pipe communicating from the Boiler to the Receiver and N *n* the loweſt Gage-Pipe; alſo O *o* the higheſt Gage-Pipe, and a Valve at P kept down by the Steel-yard P Q and the Weight Q.

S S. THE Surface of the Water in the Boiler, which muſt be lower than the Bottom of the ſhort Gage-Pipe at *o*, and higher than the Bottom of the long Gage-Pipe at *n*.

D I. THE Steam-Cock with the Key K kept down by the deſcending Screw L, held by the Gibbet D L, whilſt the Handle K is either turn'd to *k*, to receive the Steam coming from the Boiler; or to K, to ſhut out the Steam and admit a Jet of cold Water coming from the aſcending Pipe E E 2, thro' the Cock M, which muſt be open during the Operation.

N. B. THIS Cock is more fully deſcrib'd in *Fig.* 2.

EEGZ.

* He had put up an Engine for Mr. *Ball* at *Camden* Houſe at *Kenſington*, that went very well with one Receiver.

Lect. XII. Plate 40. EEGZ. The *Horse* or Pipe with several Elbows, which is solder'd to the forcing Pipe EE2 at E, the sucking Pipe ZH at Z, and the Receiver at F. This Horse contains the sucking Valve at G and the forcing Valve at F, which are easily come at by unskrewing I, to loosen the Strap 2, and let down the Flanch 3, as shewn in *Fig* 2.

R. The Cistern communicating with the forcing Pipe by a Cock and small Branch as Y, to fill the Force-Pipe upon occasion.

H. A Box with Holes to keep out Dirt from coming up with the Water from the Bottom of the Well X.

I. The spreading Plate, to make the Steam and the Water alternately be divided into little Jets.

bc. The Surface of the Steam pushing down the Water, in order to drive it up again into the Force-Pipe EE thro' the Valve E.

V. The Door of the Fire-Place, and W the Ash-Hole.

Figure 2. The Machinery of the Horse from 1, 2, 3, *Fig*. 1. is here described: 1 is the Screw, which going thro' the Stirrup 2, presses on the Piece of cast Iron 3, which is made tight to the Brim under it by double Canvas, whilst the Returns of the Stirrup draw up the Ring 4 under the Brim to support it.

5, 6, 7. Is the Key of the Steam-Cock, having an Hole on the Side at 6, which goes down thro' the Bottom of the Key, to throw down into the Receiver the Steam and Jet of Water alternately.

This Key has a Notch at 7, to take in the Water from the Force-Pipe, and convey it to the Boiler, when it is charged again with Water.

See the two Sections of the Cock *and* Key.

The Operation of the Fire-Engine improv'd from Savery, *or rather from the Marquis of* Worcester.

The Operation.

Take off, or turn over your Steel-yard, and open the Cock O of the short Gage-Pipe O*o*; then having put a long Nail or any Piece of Iron under the Valve to keep it up, pour in your Water at the Valve, and as the Water goes down, the Air will blow out at O, till the Surface of the Water comes up above the Bottom of the short Gage-Pipe at *o*; then the Boiler is sufficiently fill'd.

Then having shut the Steam-Cock DI from communicating with the Boiler, and likewise shut the two Gage-Cocks upon the Boiler at N and O, put the Steel-yard on the Valve with its Weight Q near P, and light your Fire. For a small Height, the Engine may work when the Weight is very near P; but for a great Height, it must be further. In trying

Plate 40.

trying your Boiler, that you may be ſure your Steel-yard Weight is not too heavy, remove it, Notch by Notch as you increaſe your Fire, till it cauſes the Weight to riſe at the laſt Notch at Q.

N. B. YOU may faſten a String to pull up the Steel-yard on occaſion, as you make the ſtrongeſt Trial; that you may be certain the Weight is not too heavy: and take care that no additional Weight be put to the Steel-yard Weight.

ALL being ready, and the Steam beginning to lift the Valve, turn the Handle of the Steam-Cock on the Receiver from K to *k*, to let in the Steam from the Boiler along CD, firſt opening a ſmall Hole, and then the full Bore: then the Steam ſpreading thro' the ſmall Holes of the Plate at I, puſhes on the Surface of the Water at *b c*, till the Water comes down to the forcing Valve F, which you will hear fall when all the Water is gone out of the Receiver, whoſe Out-ſide will feel very hot at that time. *N. B.* It is ſuppos'd that you have fill'd the Receiver with Water before you begun, which is done by taking out the Key of the Cock under the Screw L, which you have ſcrew'd up a little and turn'd off with the Gibbet L D. You may greaſe the Key of the Cock as you put it on again.

THE forcing Pipe being now full, and having the Cock M open, turn back the Handle from *k* to K; a Jet of cold Water will ſpout in thro' the ſpreading Plate I among the Steam, which it will immediately condenſe, and the Air preſſing in the Well will puſh the Water up into the Receiver, which will immediately fill it, and the Receiver will feel cold quite up to I. Then turn the Handle to *k* as before, which will admit the Steam and drive out the Water quite to F, then return the Handle to K to admit another Jet, and ſo on.

THIS Machine may work about 4 or 5 Hours before it is time to give over; which you may know when the Cock N, as well as the Cock O, being opened, gives Steam; becauſe then the Surface of the Water in the Boiler being below the Bottom of the longeſt Gage-Pipe, is too low, and the Boiler in danger of being burned.

WHEN both Cocks give Steam, there is too much Water in the Boiler, and ſome muſt be boil'd away by opening the Valve till the Cock O comes to give Steam when the Water boils.

SO that when the Cock O open'd gives Steam, and the Cock N open'd gives Water, the Boiler is in right order.

WHEN you would repleniſh the Boiler, you may either remove the Fire firſt, or let out the Steam thro' the Cocks; and in the mean time proceed as follows:

TURN

Lect. XII. Plate 40. TURN the Handle K from you behind L, which will bring the Notch of the Key of the Cock (mark'd 7 in *Fig.* 2.) to ſuch a Situation as you may ſee in the middle Drawing of *Fig.* 2. and then (the Cock M being ſtill open, as well as the Cock Y) the Water will run from the Ciſtern thro' the forcing Pipe and Steam Pipe into the Boiler, without going into the Receiver (which you may have fill'd before if you pleaſe) the Steel-yard being off of the Valve, and the Cock O open, to let out the Air as the Water comes in.

To know when you have Water enough in the Boiler, obſerve when the Cock O ceaſes to blow, and the Valve (which you muſt not now have prop'd open) dances: Turn back your Handle to K, ſhut the Cock Y, and all is done.

ACCORDING to this Improvement, I have cauſed ſeven of theſe Fire-Engines to be erected ſince the Year 1717, or 1718. The firſt was for the late Czar *Peter* the Firſt, for his Garden at *Peterſburgh*, where it was ſet up. The Boiler of this Engine was ſpherical (as they muſt all be in this way, where the Steam is much ſtronger than Air) and held between five and ſix Hogſheads; and the Receiver held one Hogſhead, and was fill'd and emptied four times in a Minute. The Water was drawn up by *Suction*, or the Preſſure of the Atmoſphere, 29 Foot high out of the Well, and then preſs'd up 11 Foot higher. The Pipes were all of Copper; but ſolder'd to the *Horſe* with ſoft Solder, which I knew would hold very well for that Height: and I did not care to venture either upon a greater Quantity for that Height, or a greater Height for that Quantity. For if the Quantity was larger, then the Boiler muſt be greater, and the Steam of the ſame Force would have a greater Surface to act upon, which might burſt the Boiler, or require it to be made much thicker.

ANOTHER Engine of this ſort, which I put up for a Friend about five-and-twenty Years ago, drew up the Water 29 Feet from the Well, and then it was forced up by the Preſſure of the Steam 24 Foot higher into a Ciſtern holding about 30 Tons ſet up at the Top of a Tower, in order to run down again thro' a Pipe of Conduct, and play ſeveral Jets in the Gardens. But ſometimes no Jets being play'd, the Water was at the Height of about 6 or 8 Foot diſcharged out of the Force-Pipes to fill the Ponds and water Meadows in dry Weather, which it did with a leſs Strength of Steam than what drove the Water into the Tower; or if the ſame Strength was kept up, one might make 8 or 9 Strokes in a Minute, inſtead of about 6 when the Water was driven up into the Ciſtern. Upon the Safety-Valve there was a Steel-yard, the Place of whoſe Weight ſhews

ſhews the Strength of the Steam, and how high it was capable of raiſing Water. But when the Weight was at the very End of the Steel-yard, the Steam then being very ſtrong, would lift it up, and go out at the Valve rather than damage the Boiler. But about three Years ago, a Man who was entirely ignorant of the Nature of the Engine, without any Inſtructions undertook to work it; and having hung the Weight at the farther End of the Steel-yard; in order to collect more Steam to make his Work the quicker, hung alſo a very heavy Plumber's Iron upon the End of the Steel-yard. The Conſequence prov'd fatal, for after ſome time the Steam, not being able with the Safety-Clack to raiſe up the Steel-yard loaded with all this unuſual Weight, burſt the Boiler with a great Exploſion, and kill'd the poor Man who ſtood near with the Pieces that flew aſunder; there being otherwiſe no Danger, by reaſon of the Safety-Valve made to lift up, and open upon occaſion.

THESE Accounts ſhew how high, and in what Quantity this kind of Fire-Engine can ſafely raiſe the Water. About as much Fire as a common large Parlour-Fire was ſufficient to work this Engine, and raiſe 15 Tons per Hour. So that if the Ciſtern be kept full, you may ſet your Jets a playing to entertain your Friends at any time, and then ſend a Man to light the Fire under the Boiler, which will raiſe Water to ſupply your Jets before your Ciſtern be empty: ſo that you may play your Jets as long as the Fire burns; and no longer, ſpending only Coals when you want Water. This Engine, according to my Method, conſiſts of ſo few Parts, that it comes very cheap, in proportion to the Water that it raiſes; but has its Limits, as we ſaid before.

THE Leaver Engine, often call'd *Newcomen*'s, has its Limits the other way. That is, it muſt not be too ſmall; for then it will have a great deal of Friction, in proportion to the Water that it raiſes, and will coſt too dear, having as many Parts as the largeſt Engines, which are the beſt and cheapeſt, in proportion to the Water they raiſe: The Friction being always as the Diameter, whereas the Water rais'd is as the Square of the Diameter of the Cylinder; and a much greater Part of the whole Power is employ'd to move all the little Machinery than in a great one. I had an experimental Proof of this at *Weſtminſter* in the Year 1728, or 9. when Mr. *Jones* (commonly call'd *Gun-Jones*) built a working Model of the Leaver-Engine in my Garden, (which Model he had a mind to preſent to the King of *Spain.*) I had at the ſame time near the Place where he erected his Engine, one in *Savery*'s way, which rais'd ten Tons an Hour about 38 Feet high.

HE made his Boiler of the exact Size of mine, and his Cylinder was ſix Inches Bore, and about two Feet in Length. When his Model or

Lect. XII. Leaver-Engine was finiſh'd, it rais'd but four Tons per Hour into the ſame Ciſtern as mine. It coſt him 300 *l.* and mine, having all Copper Pipes, had coſt me but 80 Pounds.

SECTION XVI.

NOW we come to conſider the moſt common Caſes in Hydraulicks, which are thoſe where there is a Neceſſity of raiſing Water, and we can have only Men, or Horſes to do it. Here, inſtead of hearkening to quack Engineers, who in oppoſition to each other cry up their own particular Engines; we muſt know for certain how much Water one Man (or any number of Men) can raiſe to a certain Height in a certain Time, by the help of the beſt Engine; and the Knowledge of this *Maximum* will ſhew what we can expect to have done, by the number of Men or Horſes that we can ſpare to employ in this Work. By this means we ſhall not be impos'd upon by knaviſh or ignorant Pretenders. And here the Ignorant, if he be honeſt, is more dangerous than the thorough-pac'd Knave; for the Conceit of the Ignorant will give him ſuch a Confidence, as eaſily to perſuade thoſe of his Skill, who profeſs to have none of their own.

ONE might from ſuch mechanical Principles as are learn'd in the firſt Volume deduce ſo much of this Knowledge, as to be certain how much Water at a Medium a Man can raiſe in an Hour to a certain Height, without making any hydroſtatical or hydraulick Experiment; if People could be brought to believe that it is the ſame thing to carry up into any Room a certain number of Pounds of Lead, or Pints of Water, in the ſame time. But a few Perſons, unleſs they are vers'd in Mechanicks, imagine, that it is *exactly the ſame Labour*, and will *take up as much Time* to carry a Ton Weight of Wheat into a Granary, as to fill a Ton with Water in the ſame Place, either carrying it up in Pails, or pumping it up with a good Pump. The falſe Notion of ſome of the Ancients, *viz. That Water does not weigh in Water*; or the Thoughts that a Column of Water may be balanc'd to Advantage, or that the Fluidity of Water takes off its Weight, leads many People into Error. For this reaſon I have choſen to fix my *Maximum* of what a Man or Horſe can do in this caſe from hydraulick Facts; by obſerving what Men have actually done with the beſt Pump or Water-Engines in uſe; and take the Medium. Afterwards I ſhall ſhew, that the ſame will come out by mechanical Calculation; for a Man turning a Winch or Handle to wind up Weights, works neither eaſier nor harder than when he winds up Water; and if his Eyes were ſhut, he would not know which he was doing.

SECTION

Plate XXXVI.

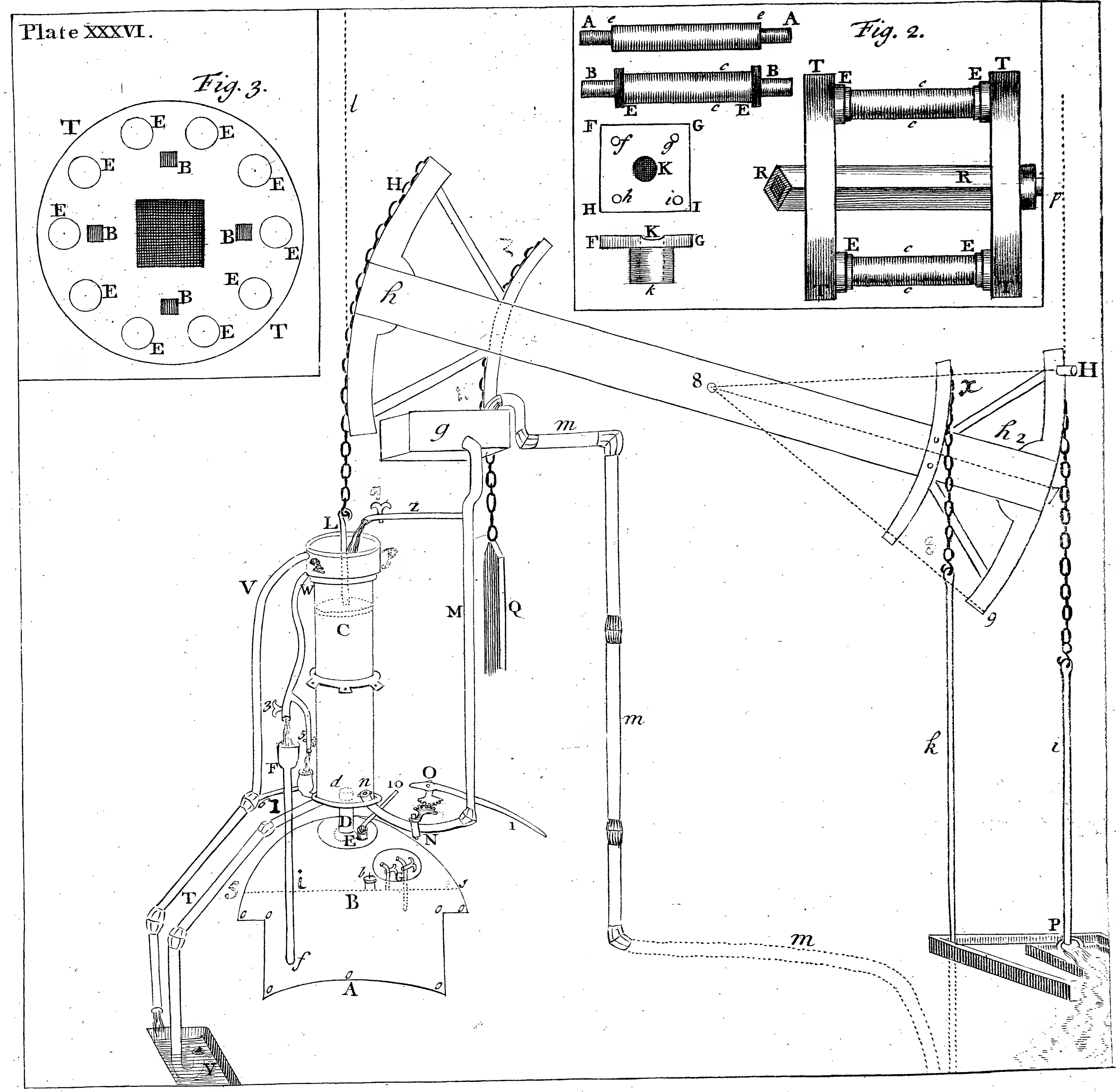
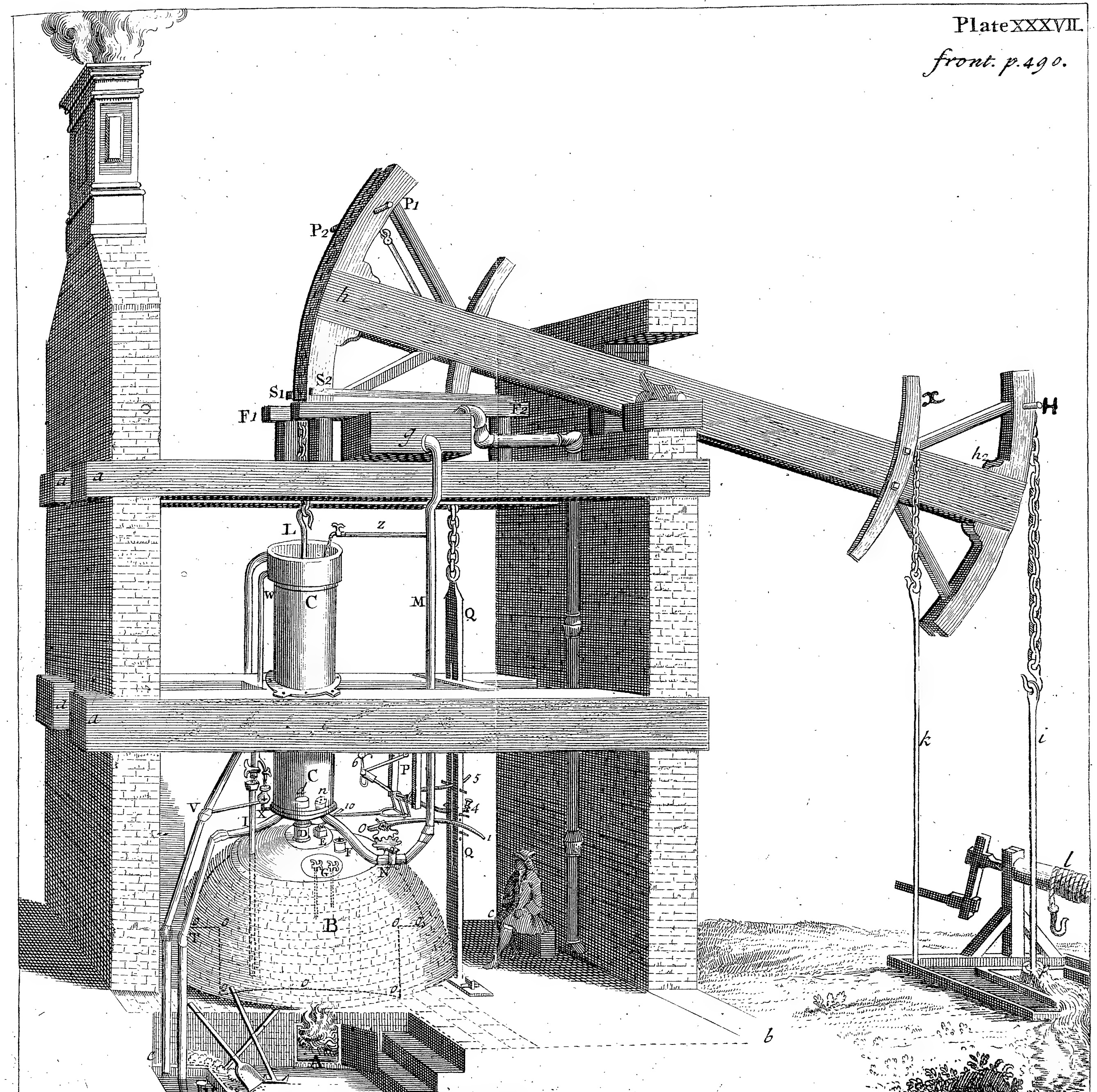


Plate XXXVII.

front. p. 490.



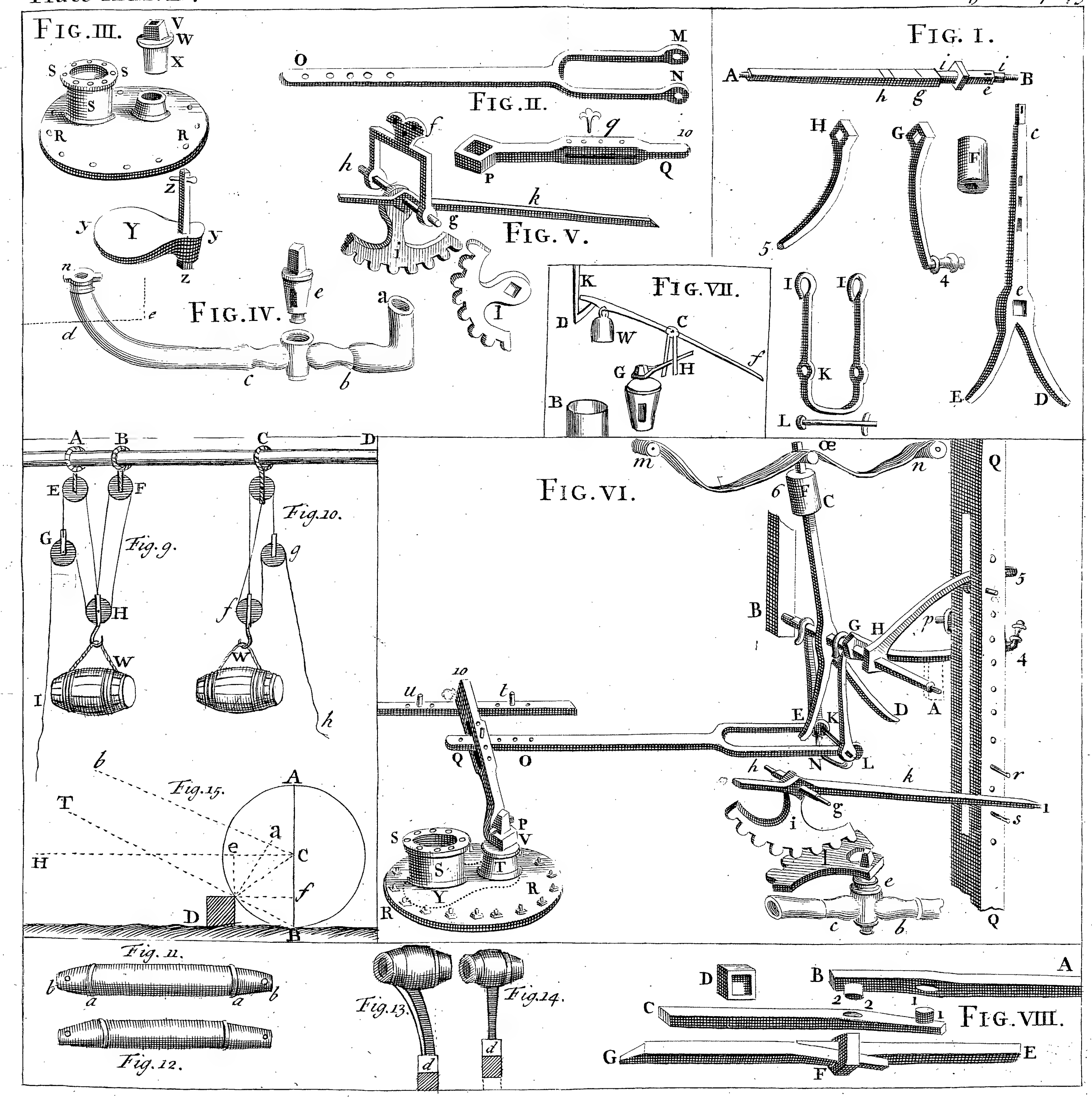


Fig. I.
Fig. II.
Fig. III.
Fig. IV.
Fig. V.
Fig. VI.
Fig. VII.
Fig. VIII.
Fig. 9.
Fig. 10.
Fig. 11.
Fig. 12.
Fig. 13.
Fig. 14.
Fig. 15.

Plate XXXIX. front p. 459

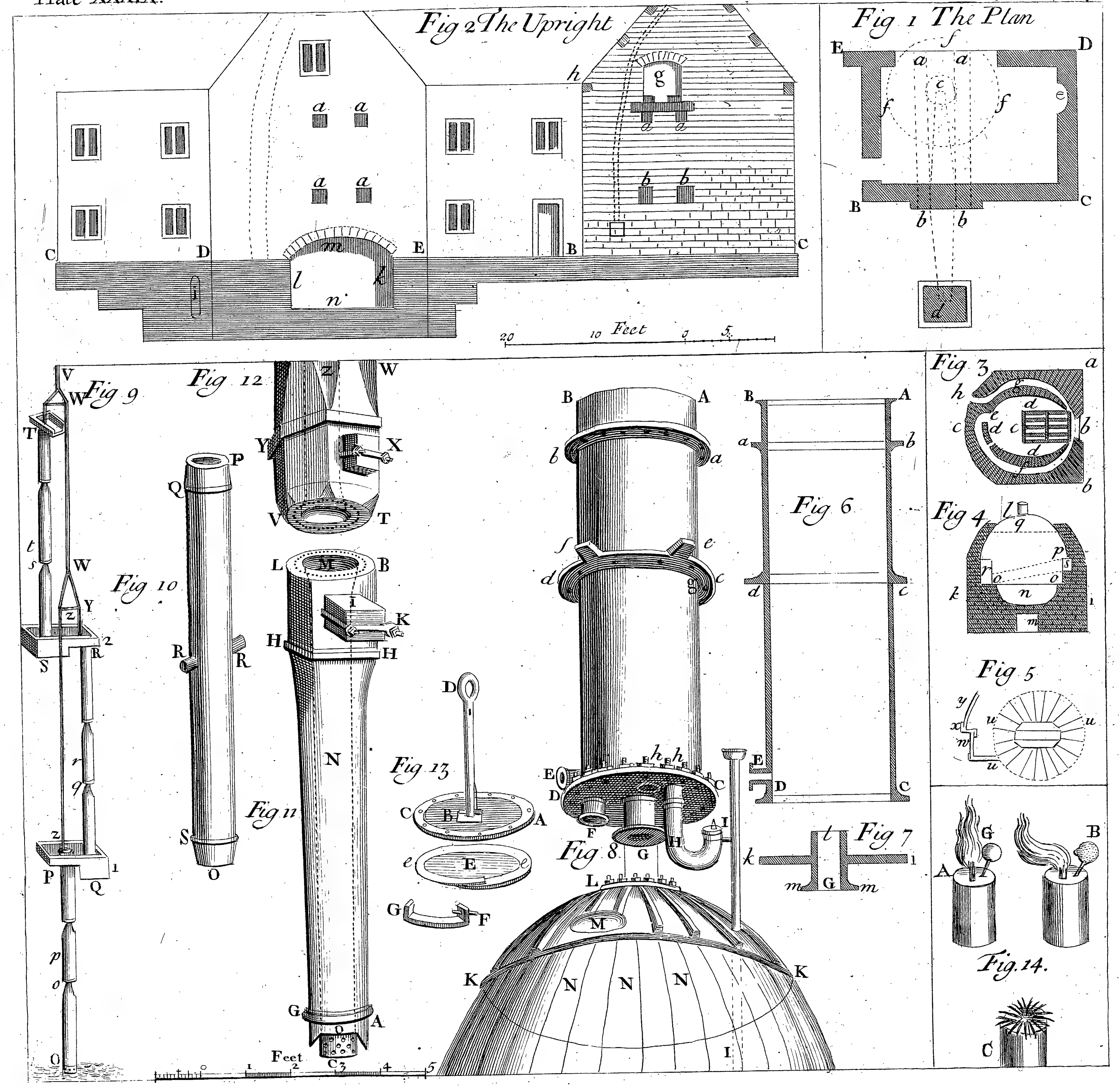
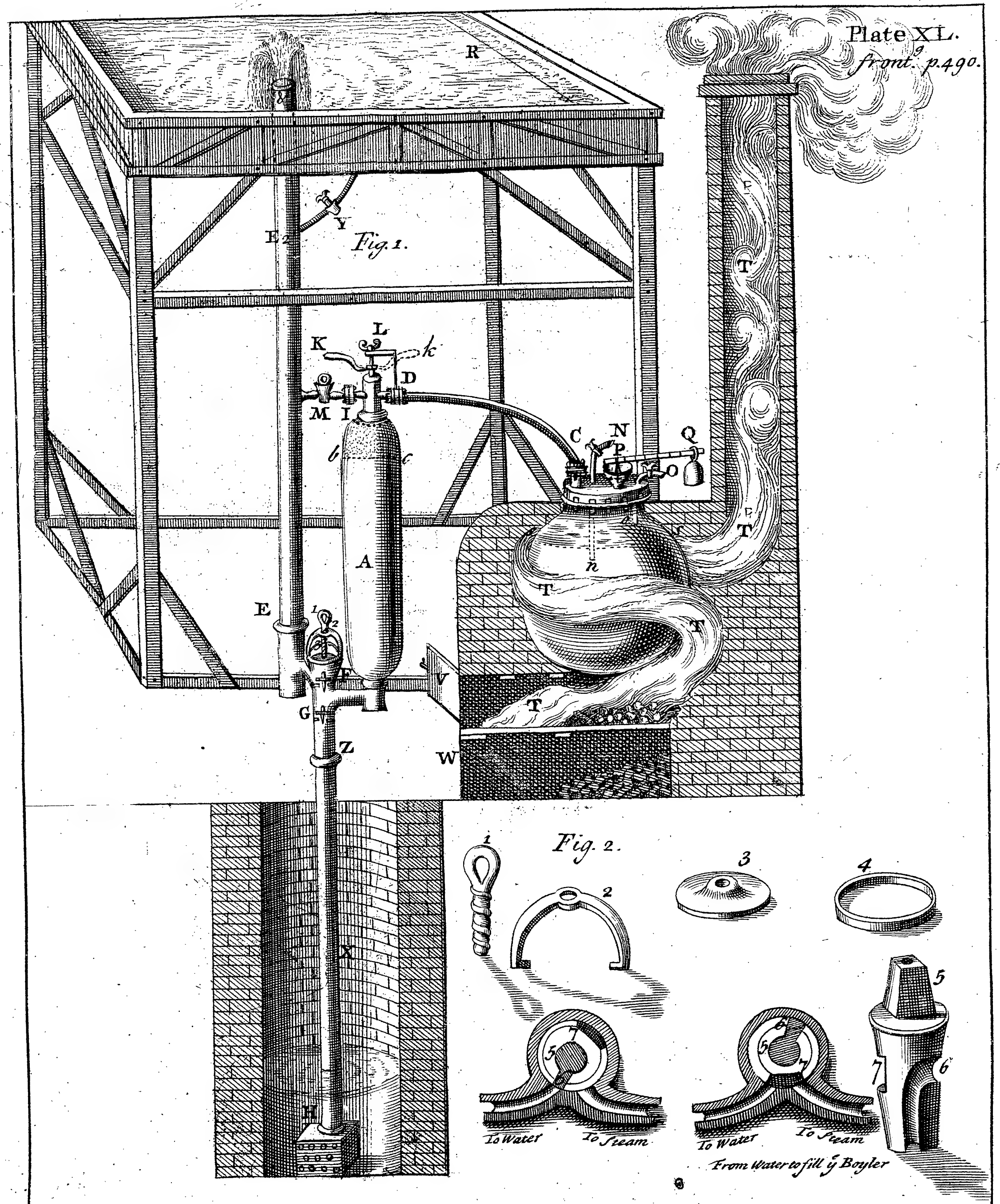


Plate XL.
front. p.490.



SECTION XVII.

THE first of these Engines I shall consider, is a Contrivance of the late Mr. *Joshua Haskins*, to avoid all Friction of Solids in Pumps, by the Substitution of Quicksilver instead of Leather.

Plate 41.

A Description of an Engine to raise Water by the help of Quicksilver, invented by the late Mr. Joshua Haskins, *and improv'd by the Author.*

MR. *Haskins* finding that all hydraulick Engines working with Pumps lose a great deal of Water, (always giving less than the number of Strokes ought to give, according to the Contents of the Barrels;) and that when the Pistons are new leather'd to prevent that Loss, the Friction is much increas'd, and the Engines are subject to Jerks, which in great Works do often disorder an Engine for a great while, by breaking some of the Parts; contrived a new way of raising Water without any Friction of Solids; making use of Quicksilver instead of Leather, to keep the Air or Water from slipping by the Sides of the Pistons in the Barrels where they work: hoping thereby to prevent all the abovesaid Inconveniences; and also to have Water-Engines less liable to be out of order than any yet made.

THE first Experiment he made with an Engine that he set up at my House about two Years ago, which I repeated before the Royal Society in a Model: and tho', by the ill Contrivance of the Parts, it did not raise near the Quantity of Water that the Invention is capable of; yet I shall describe the Machine here, because it will serve for the better understanding of our present Engine.

Plate 41 and 42. *Fig.* 1.

d d d d represents a *Lignum Vitæ* Plug or Piston, (which Mr. *Haskins* call'd a Plunger) about six Feet long, made heavy enough with Lead at top to sink into *Mercury*, which is before-hand pour'd into the Barrel D 1 D 2 up to *m m*. The Chain E 1 E 2, join'd to the Piston and the Power that moves it, being let down till the Piston comes to D 2, the *Mercury* rises to the same Height in the Barrel, and in the Receiver R, (which it fills) namely to *n n*, as appears in the Figure. Then drawing up the Piston till its Bottom is come to *m m*, the *Mercury* coming out of the Receiver down to *o o* makes a *Vacuum*, and the Weight of the Atmosphere causes the Water to rise up thro' the Sucking-Pipe A 1 A 2, and Valve V into the Receiver where the *Mercury* was

 before.

Lect. XII. Plate 41 and 42. before. Upon letting down the Piſton again, the *Mercury* riſes into the Receiver, and drives up the Water thro' the Elbow B, the forcing Valve *u*, and ſo up the forcing Pipe *a* 2 *a* 1: But when once the forcing Pipe (which here was 46 Feet high) is full, before any *Mercury* can enter into the Receiver, and force any Water out of the Top of the Pipe *a* 1, the *Mercury* between the Piſton and the Barrel muſt riſe up to *q q* near 3 $\frac{1}{2}$ Feet above the Bottom of the Receiver; and as it continues to riſe up to *p p*, the Water is thrown out with a Velocity proportionable to the Height that the *Mercury* is rais'd above the 14th Part of the Height of the Water. Now tho' the Friction of Solids is here avoided, it is plain that the *Mercury* muſt move from *m m* to *q q* without raiſing any Water, and that it can only force in going from *q q* to *p p*, and only ſuck in falling from *o o* to *m m:* And unleſs the Piſton is ſtopp'd a little while when at loweſt, the Water won't have time to run out: So likewiſe the Piſton muſt be ſtop'd when at higheſt, that the Receiver may have time to fill.

MR. *Haſkins* likewiſe propos'd another way, repreſented in *Fig.* 2. where the ſame Letters repreſent the ſame Parts, only the Barrel is moveable by the two Chains E 1 and E 2, and inſtead of a ſolid Piſton, the hollow Cylinder C 1 *c c* is fix'd, and the *Mercury* moving up and down in the lower Part of it, ſucks and forces the Water thro' the Elbow. The Figure repreſents the Engine ſucking, by means of the *Mercury* hanging from *o o* to *m m:* In order to force, before any Water can be driven out, the *Mercury* in the inward Cylinder muſt deſcend from *o o* to *m m*, and riſe up to *p p* between that Cylinder and the Barrel; ſo that here alſo a great deal of Time is loſt; beſides the great Quantity of *Mercury* uſed, which is very expenſive; becauſe as much *Mercury* is mov'd every Stroke as there is Water rais'd.

THESE Difficulties very much puzzled Mr. *Haſkins*, and quite diſcouraged ſome other Perſons that had got the Secret of the Invention, and were ſetting up againſt him. But when I had conſider'd the Matter a little, tho' I had not Time to contrive a Machine for it, I told him that a little *Mercury* might be made to raiſe a great Quantity of Water, and there ſhould not be ſuch a Loſs of Time as in his Engines; but that I would have him find it out before I aſſiſted him farther. In a little time he found out the Contrivance repreſented in *Fig.* 4. and afterwards that of *Fig.* 3. which laſt was what I had thought of: And both theſe were alſo found out by the late Mr. *William Vreem*, who was an excellent Mechanick.

Fig.

Plate 41 and 42.

Fig. 3.

HERE the Barrel is mov'd as in *Fig.* 2; but the Plug *d d d* taking up a great deal of Space, there is occaſion for no more *Mercury* than what will make a concave Cylinder or Shell up to *p p* between the Barrel D 1 D 2, and the hanging Cylinder C 1 C 2 *c c*, when the Stroke is made for forcing; and a concave Cylinder between the Plug C 1 C 2 *c c*, when the Suction is made. I gave Mr. *Haſkins* the Proportions for an Engine this way, of which he made a Draught, and ſhew'd to the Right Honourable the Earl of *Macclesfield* a few Days after. This I mention here, that no body may endeavour to get a Patent for this Invention, to the Prejudice of Mr. *Haſkins*'s Aſſignees; who, ſince his Death, have deſired me to aſſiſt them in perfecting the Engine.

Fig. 4.

HERE the Barrel with a third Cylinder *d d d d*, inſtead of the Plug, of *Fig.* 3. is lifted up and down every Stroke, and the Water paſſes thro' *d d d d*, the *Mercury* making a Shell ſometimes between the middle and inner Cylinder, as in the Suction; and ſometimes between the Barrel and middle Cylinder, as in the forcing Stroke.

MR. *Haſkins* had contriv'd ſuch a Machine as is repreſented by this fourth Figure, and beſpoke the ſeveral Parts before he died; and therefore when I was deſir'd by his Aſſignees to direct the ſetting up the Machine, I was oblig'd to make uſe of the Pieces already made, in order to ſave the Expence of a new Engine: And now the whole put together with ſome Alterations, make the Engine repreſented by *Fig.* 5. as it is ſet up at my Houſe in *Weſtminſter*, and by the Force of one Man, raiſes a Hogſhead of Water in little more than a Minute and a half to the Height of 27 Feet. All the Fault of the Machine of *Fig.* 5. is, that the Pendulum Handle F *f* is too long, and the Bottom of the middle Cylinder C ought to be juſt in the middle of the Height to which the Water is to be rais'd, ſuppoſing three Copper Cylinders to be as they are here: If likewiſe the Barrel D 1 D 2 work'd under the forcing Pipe, the Lift would be eaſier. Therefore I deſcribe the Machine in the ſmall Alteration repreſented in *Fig.* 6.

THE ſucking and forcing Pipe and Valves are mark'd with the ſame Letters as in the other Figures: and the Chains E1, E2, muſt be ſuppos'd to hang from ſuch Pulleys, and to be mov'd by ſuch a Pendulum as is in *Fig.* 5. The Barrel in D1, D2, (called otherwiſe the outer Cylinder, and repreſented by the ſame Letters in *Fig.* 7.) has within it another Cylinder

Lect. XII. Cylinder called the inner Cylinder or Plug, as *dddd*, *Fig.* 7. between which two Cylinders a certain Quantity of Mercury is poured in, and the hanging Cylinder C coming down into the Mercury, a Stroke of 13 Inches may be made by the Motion of the Barrel, which in going down ſucks by making a *Vacuum* in C, and in going up forces the Water out of the top of the forcing Pipe, performing the Office of a common Piſton; only that inſtead of Leather to make it tight to the Cylinder C, there is always a thin Shell of Quickſilver either between the middle Cylinder C, and the inner one, (*dddd*, *Fig.* 7.) as happens when the Suction is made, or between the middle and outer Cylinder, as happens in lifting up the Barrel to force. In the Suction, the Mercury is higher in the inner Shell than in the outer Shell, by an Height equal to a little more than $\frac{1}{14}$ Part of the Height of the Barrel above the Water to be raiſed: And in forcing, it is higher in the outer Shell than in the inner by a little more than $\frac{1}{14}$ of the Height of the Pillar of Water to be forced. And therefore, if the Water is not required to be raiſed above 64 Feet, the Barrel ſhould move ſo as to make the middle of its Stroke at the Height of 30 Feet, or at the middle of the way from the Water to be rais'd to the Delivery at top.

Plate 41, & 42.

THE 7th Figure drawn by a larger Scale, repreſents the three Cylinders which are here made of Copper, in their juſt Proportions: And for the ſake of thoſe that would conſider this Matter fully, I have here given their Lengths, Diameters within and without, and Thickneſs.

	Outer Cylinder or Barrel, D 1, D 2.	Middle or hanging Cylinder, in which the Stroke is made C 1, C 2, *c c*.	Inner Cylinder or Plug cloſed at top by a Cap, and moving up and down with the Barrel to which it is join'd at bottom *dddd*.
	Inches	*Inches.*	*Inches.*
Length	30	29,0	31,2
Diameter within	6,74	6,35	6,03
Thickneſs	0,10	0,08	0,13
Diameter without	6,94	6,51	6,29

HERE BB repreſents part of the Elbow of *Fig.* 5. or of the forcing Pipe of *Fig.* 6. But as the Spaces between the Cylinders are ſo ſmall as not to be viſible even in a large Draught made by a Scale; I have here given three more Draughts of the three Cylinders where the Height is agreeable to the Scale of the 7th Figure, but the Diameters of the middle and inner Cylinders are made leſs than they are in the Engine, to make the

he Space between (where the Mercury rifes and falls) vifible; and the Cylinders themfelves are reprefented by fingle Lines.

THE Quantity of *Mercury* ufed in this Engine is 36$\frac{1}{2}$ Pounds, which being pour'd in between the outer and inner Cylinder, rifes up to the Height of 16 Inches. Plate41,&42.

WHEN the Barrel is pull'd up (as in *Fig.* 9.) fo as to have the middle Cylinder within an Inch of the Bottom of the Barrel; the Mercury on both fides the middle Cylinder will rife up to the Height of 23,1 Inches, that is, about two Inches below the Cup D1, to the Line *qq*.

WHEN the Barrel is going down to fill the fucking Pipe and middle Cylinder C, the Mercury in the inner Shell will be 25 Inches high, and only 13 in the outer Shell, *Fig.* 9. where the fhaded Part reprefents the ☿.

AT the End of the fucking Stroke the Mercury is up to the top of the inner Cylinder, and fcarce an Inch in the outer Shell, *Fig.* 8.

IN raifing the Pifton from forcing to fucking, the firft 1$\frac{1}{4}$ Inch drives the Mercury out of the inner Shell, and raifes it in the outer Shell 13,28 Inches.

THE Depth of an Inch of Water in the middle Cylinder above the inner one or Plug is equal to a Space in the outer Shell of 13,28 Inches, and $\frac{1}{4}$ of an Inch is equal to the fame Height in the inner Shell.

THEREFORE when the Mercury is equally high in both Shells, a Motion of $\frac{1}{4}$ of an Inch of the Barrel will charge for Suction. That is, upon letting down the Barrel only $\frac{1}{4}$ of an Inch, the Preffure of the Atmofphere in the outer Shell will raife the Mercury in the inner one 13,28 Inches, at the fame time that it pufhes up the Water from the Well 13 Foot and a half high into the fucking Pipe. And when all the Pipes are full, if the Mercury be equally high in both Shells, upon raifing the Barrel one Inch, the Mercury will rife 13,28 Inches in the outer Shell, which I call charging for forcing; becaufe in continuing to raife the Barrel, the forcing Valve immediately rifes, and the Water comes out at the top during the reft of the Stroke which is 12 Inches, and delivers 1,6 Gallon of Water, Wine-Meafure.

Fig. 10. reprefents the forcing Stroke half way up; with the ☿ 17 Inches in the outer Shell, 4 Inches in the inner, and the whole Space at bottom under the middle Cylinder 7 Inches.

FROM this it appears that in the whole Stroke of 13 Inches in the Length, there is only $\frac{1}{4}$ of an Inch loft to charge for Suction, and in the next Stroke, which is likewife of 13 Inches, there is only one Inch loft to charge for forcing; fo that in a Motion of 26 Inches, there is but 1$\frac{1}{4}$ Inch, or about $\frac{1}{20}$ Part ineffectual. But this is owing to the too large Space

Lect. XII. Space of the outer Shell, which contains 4 times more than the inner one, becaufe the Cylinders were only hammer'd, and not turn'd: for if the Plate41, &42. outer Space had been no bigger than the inner, then $\frac{1}{4}$ of an Inch of the Stroke would have charg'd for forcing; fo that only $\frac{1}{2}$ an Inch in 26, or $\frac{1}{52}$ Part of the whole Stroke would have been ineffectual; and in that cafe $\frac{2}{5}$ of the Quantity of Mercury, or a little more than 12 Pounds, would have been fufficient.

THERE may ftill lefs Mercury be ufed if the middle Cylinder be made of Plate-Iron, turn'd on the Outfide, and bored within, the outer Cylinder bored, and the inner one turn'd; fo that if the Work be well perform'd, eight or ten Pounds of Mercury will be fufficient in this Engine, tho' the Bore of the middle Cylinder, or Diameter of the Pillar of Water which is rais'd, be of 6,35 Inches. If the Bore of the faid Cylinder was but 8 Inches, lefs than 3 Pounds of Mercury would fuffice, and lefs than 6 if there were two Barrels, in order to keep a conftant Stream thro' a Pipe of almoft the fame Diameter. This will very much leffen the Expence of Mercury, which would otherwife be an Objection againft this Engine; and by making the inner and outer Cylinder of hard Wood, as Box or *Lignum Vitæ*, the Coft of the Engine may ftill be reduced. But if the Engine be very large, caft Iron bored will be proper for the outer Cylinder, and caft Iron turn'd on the outer Side for the inner Cylinder or Plug, and hammer'd Iron bored and turn'd for the middle Cylinder.

THERE is an Objection, which feems at firft to take off the intended Advantage of this Engine, which is this, *viz.* That inftead of the Friction of the Leather of a Pifton, when we lift up one Barrel to force, the Refiftance that the Mercury finds to rife in the outer Shell is at leaft as great as the Friction that we avoid. Now that Refiftance is never greater than the Weight of a concave Cylinder of Mercury, whofe Height is the greateft to which the Mercury rifes in the faid Shell, and the Bafe is the Area of the Shell it felf. This Weight in our Engine is equal to 57,5 Pounds, and therefore one would think it greater than the Refiftance made by the Friction of a Pifton. But if it be confider'd, that in the Defcent of the Barrel for fucking, the Mercury fhifts immediately into the inner Shell, rifing to the fame Height, and ftill keeping the fame Bafe; the aforefaid Weight of 57,5 Pounds helps down the Barrel, and facilitates the overcoming of the Force of the Atmofphere; confequently the Weight of the Mercury being balanced is no hindrance, whether you work with a fingle or a double Barrel.

THERE remains only then the Hindrance by lofs of Time, in the Beginning of any Stroke: But I have fhewed that to be but $\frac{1}{52}$ Part of the Stroke. I have found that the beft Engines now in ufe generally lofe near $\frac{1}{5}$ of the

Plate XLI.
front. p.496.

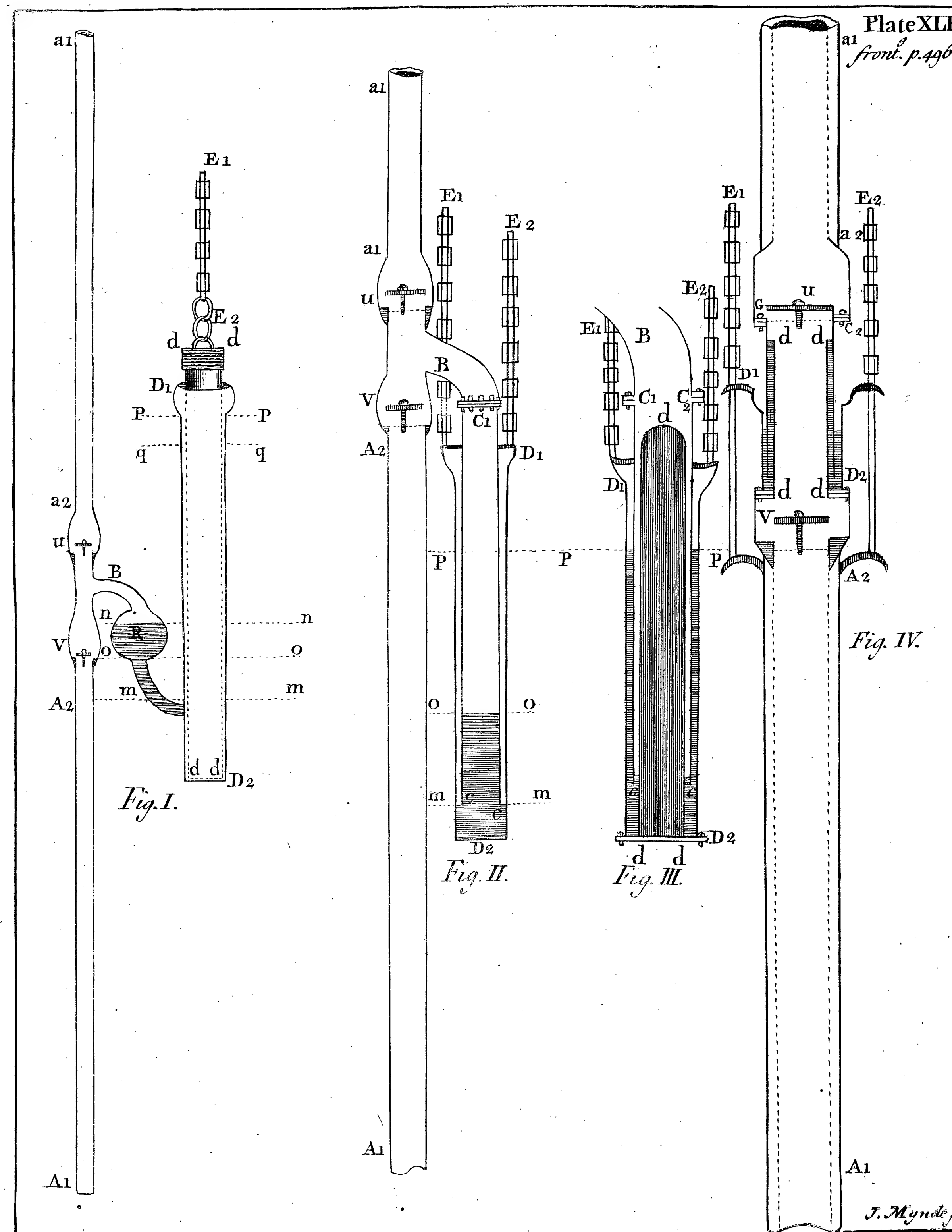
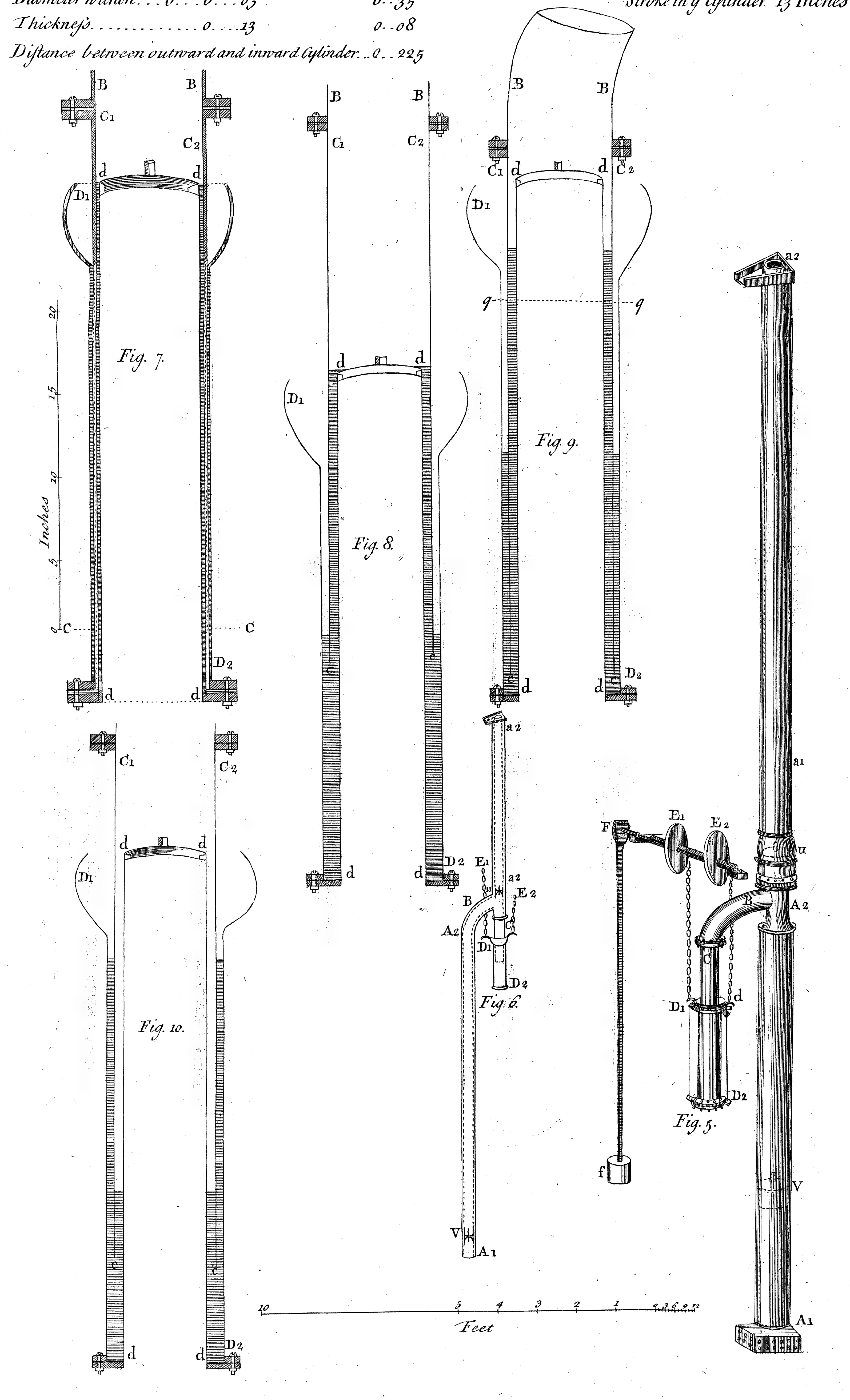


Plate XLII.
fronts p. 496.

	Inner Cylinder Feet. Inches. Tenths.	Second or Middle Cylinder Feet. In. Tenth.	Outward Cylinder F. In.
Length	2..7..2	2..5..0	2..6
Diameter within	0..6..03	6..35	
Thickness	0..13	0..08	

Distance between outward and inward Cylinder..0..225

Depth of the Cup 5 Inches
Diameter 10.5
Length of ye Pendulum 9 Feet
Stroke in ye Cylinder 13 Inches



the Water that they ought to give, according to their Number of Strokes. Lect. XII. And Mr. *Henry Beighton*, an ingenious Member of this Society, having a great many times meafured the Water that is raifed by Engines in Mines, Plate 41 and 42. found that fome Engines loft $\frac{1}{4}$, and none ever loft lefs than $\frac{1}{5}$ of what they ought to give, according to the Number of the Strokes in their Pumps, whatever auxiliary Powers they were mov'd with.

THERE is indeed another Objection, but fcarce worth notice; which is, that fome Particles of Mercury will mix with the Water that is rais'd, and make it unwholefome; but no body that confiders fpecifick Gravity, will imagine any fuch thing. However, to fatisfy thofe that might ftill apprehend it, it is to be obferv'd, that none of the Water that is rais'd comes near the Mercury: For in the Cylinder C, and Part of the Elbow B, (*Fig.* 5.) there is always above the Mercury a certain Quantity of Water that rifes and falls with the Barrel, and never goes into the forcing Pipe. The fame happens alfo in the Machine of *Fig.* 6. for the Water having once run into the Cylinder C, all that is rais'd afterwards comes thro' the forcing Valve without coming down to the Mercury.

PROVIDED Care be taken to make the Barrel with its Plug tight, I don't fee that this Machine will want repair in a long time, except fome of the auxiliary Powers be out of order, which do not relate to this Invention. The Numbers given will ferve to examine the Truth of what I have afferted concerning the Motion of the Mercury: And from them one may make Tables to ferve to proportion thefe Engines for raifing any Quantity of Water to any Height according to the Power one has to apply.

SECTION XVIII.

Plate 43.

FROM this Account of the Quickfilver-Engine it is plain, that one Man raifes a Hogfhead of Water in a Minute 18 Foot high, (for one Hogfhead 27 Foot in a Minute and a half comes to the fame;) but when this was done, he exerted himfelf to fhew the Excellency of the Engine; for he could not hold out at that rate a quarter of an Hour. But when I made him work leifurely, as he thought he might hold it fix or eight Hours in a day, he raifed a Hogfhead but betwixt 10 and 11 Foot in a Minute. I defired Mr. *Labelye* to make Obfervations on Water pump'd out of his *Caiffons*, or Bridge-Machine, when his beft and moft fimple plain Pumps were ufed: and the Refult of many Obfervations of the Work of many or few Men, amounted to the raifing an Hogfhead of Water, at moderate Work, fcarcely 10 Foot high in a Minute. I alfo found

Lect. XII. found the same by Experiments on some particular Pump, and found 'em to come up just to the Height of 10 Foot; but something under the Quicksilver-Engine. So that I have settled this *Maximum* thus:

Plate 42. *A Man with the best Water-Engine cannot raise above one Hogshead of Water in a Minute* 10 *Foot high, to hold it all day.* But he can do almost twice as much for a Minute or two.

When we come to examine the best Engines, and those that are most cried up, as performing Wonders (that is, Men by them performing Wonders; for the particular Make of an Engine makes it perform nothing) if we look narrowly into them and measure the Water they deliver, and at what Height they deliver it; or bring to Calculation the best-attested Relations concerning them, we shall find that they don't exceed this *Maximum*, tho' they may far out-do some very bad Engine that they are compared with.

The Reverend Father *Castel*, a Jesuit, has publish'd a florid Declamation in praise of a new Hydraulick Engine with this Title,

Description Critique d'une Nouvelle Machine Hydraulique, pour l'Elevation des Eaux, de l'Invention de M. Du Puy, *Maître des Requêtes.*

That is, A Critical Description of a new Hydraulick Machine for raising Water, invented by the late Mr. *Du Puy*, Master of the Requests. In this Paper, which contains 34 Pages in a small Print 12°, the good Father is arch, witty, and florid, quotes the Scripture, and brings in Poetry and Philosophy, and compares this Engine with two very bad ones, and cries it up beyond any Machine whatever, and says it acts upon a new Principle of Mechanicks. At last he says, all (indeed) that was necessary to be said to give a Person of any Skill a true Idea of it, *That* 4 *Men in* 20 *Seconds by this Machine raise a Hogshead of Water* 25 *Foot high.*

If we bring this to a Comparison with the Quicksilver-Engine, it will appear that the Work of one of M. *Du Puy*'s Men is equivalent to the raising of a Hogshead of Water $18\frac{3}{4}$ Feet high in one Minute, (which will be only 10 Foot when a Man works all Day;) and he that works the Quicksilver-Engine, raises a Hogshead but 18 Foot high in the same time. This is a proof that M. *Du Puy*'s Engine comes up to the *Maximum*, or rather exceeds it, and therefore is a very good Engine; unless the good Father in his Zeal makes some little mistake; because in a Memorial from the Widow, the Height is only made 20 Foot. But even then it will be a good Engine; which I will here describe (from a Model that a Friend gave me) and shew its Excellencies and Errors; and where it is, and where it is not useful.

Plate

Plate 43. *Fig.* 1.

Section XIX.

NRMQKQ*m*RBN is the Wooden Frame of the Engine, having fixed to its Bottom NOPB a Box open on the under-side to set with the Engine in the Water of any Pond or marshy Ground to be drain'd. In this Box are two Pair of Bellows OC, and PC, whose Noses C where they join together are as wide as the other End. The top Board of the Box OP makes the top Board of both the Bellows, with two Holes and forcing Valves V2, V3, to receive upon occasion the Water coming from each of the Bellows, which Bellows take up their Water from the Place DD, where the Machine stands, thro' the sucking Valves V1, V4, which are fix'd to the under Boards of the said Bellows, which are alternately push'd down into the Water till their Bellows are full, and then raised up to discharge their Water thro' the forcing Valves in the upper Boards into a large Pipe V1, QTQVS; from whence the Water runs to the Place design'd through the Trough *t*TX. This is done by the Force of 4 Men working two at each End of the Leaver M*m* moveable round the Center K; which Leavers draw up the lower Boards of the Bellows by the Bars MN, and *m*B. On the right hand you see how the Bellows Board is drawn up from B to A, and forces its Water thro' the Valve V3, its Valve V4 being shut: and on the left hand the Bellows CV is depress'd, filling it self with Water thro' the Valve V1; and then the Board C being drawn up from N towards O, the Water is forced out at V2 into the common Pipe, *&c.* Here all the Resistance made is hardly any thing but the Weight of the Water rais'd; for the Pipe being suppos'd very wide, there is but little Friction against its Sides, and what remains is only the bending of the Leather of the Bellows, which being kept wet, folds very easily. The Pipe TQV2 need not be very strong, it being almost sufficient for it to be able to hold when full of Water; and therefore Tin is sufficient for that which is shewn for Trial at Mr. *Du Puy*'s House.

The best Use of this Machine is on board a Ship, because first a sufficient one will take up but 3 square Feet of Room. 2dly, It will lie so much below the Surface of the external Water, that the Men that work it will be out of Cannon-shot: and if by great chance a Cannon-Ball should break the Pipe V2T, which carries up the Water into the Trough to be evacuated, it is easy to supply that Loss by slipping on a new Pipe at V2, V3, 4. But what is of the greatest consequence is, that

 the

Lect. XII. the Friction is so little here, that half the number of Men will work it, that work their usual Ship-Pumps, and raise more Water.

Plate 43. Fig. 1. This Machine will be also of great Use to drain overflow'd Lands, marshy Grounds, or convey Water from one Fish-pond to another, whose Situation is higher. But for drawing Water from a deep Mine, or forcing the Water into a high Cistern to supply a Town, it cannot do any great Service; but will soon be spoil'd.

Whoever read with Attention what I said in *Lecture* 7, from Page 106 to 111, will find that this Machine is nothing but the hydrostatical Paradox inverted; and that when we would by this means raise the Water high, we have a much greater Pressure acting against us from the Water we would raise than barely its Weight. Whatever be the Bigness of the ascending Pipe, the Force to be overcome is equal to the Weight of a Column of Water, whose Base is the horizontal Section of the two Bellows multiplied into the Height to which we raise our Water. An easy Calculation will make this thing plain. Suppose the Bellows to be 18 Inches square, the Surface of both at the bottom Boards will be four Feet and $\frac{1}{2}$, upon which the Height of a Foot of Water weighs 281,2 Pounds, (62,5 being the Weight of a cubic Foot of Water; and this Weight, or Pressure which acts as Weight, at the Height of ten Feet, or by using the Pipe V 2 T (whatever be the Pipe's Diameter) will be increas'd to 2812 Pounds, to be lifted by the four Men; which we will allow them to be capable of lifting by the right Management of their Leavers, and making a short Stroke. But if we would lift the Water higher, we must allow 281,2 Pounds for every additional Foot in our ascending Pipe. For Example, if we add a Pipe 50 Feet high, in order to raise the Water 60 Feet, of three Inch Bore; the Weight of the Water in such a Pipe fill'd up 50 Feet high weighs but 150 ℔; but the Pressure or Weight acting on the lower Board of the Bellows would be equal to 14060 ℔: so that the two Men on each Side would have 7030 ℔. to lift, which would stop them at once. Or if they could get such a Purchase as to do it, the immense Pressure would in a few Strokes tear the Bellows all to pieces.

There needs no more to be said upon this Subject; but only to take off the Blame from myself for revealing a Secret, of which Mr. *Du Puy*'s Widow hopes to make a great Advantage. But I have reveal'd no Secret; for about 14 Years ago two Men here apply'd for a Patent for this very Engine, proposing thereby to drain Mines. I think the Name of one of the Men was *Skirret*, the other I do not remember. All the Difference was, that their Bellows were fix'd upon a little Waggon; and they had a short Sucking-Pipe under; and the Force-Pipe went

went up from the two Bellows. I oppos'd the taking out of this Patent, becauſe I thought it would be of great Hurt to the Undertakers, to lay out near 80 Pounds for what would never bring them 80 Pence; unleſs they made a Bubble of it, and drew unwary People into a Scheme to ſubſcribe Money. Lect. XII.

SECTION XX. *Plate* 43. *Fig.* 2.

THE beſt Machine of this ſort was a Pump invented by Meſſieurs *Goſſet* and *de la Deuille*, where the Piſton has no Friction. About eight Years ago it was much cry'd up beyond its real Merit, in the *French* and *Engliſh* News-papers. When I came to *Paris* about ſix Months after it was firſt ſet up; the late Monſieur *du Faye*, Intendant of the Royal Gardens at *Paris*, ſhew'd me the Experiment of it in the Garden where it was. I told him what was my *Maximum*; and that it was a good Machine if it came up to it. Accordingly we meaſur'd the Water, and found the Rate of its working to be juſt at the Rate of one Hogſhead rais'd ten Feet in a Minute, which the Men perform'd for a great while together. Plate 43. Fig. 2.

THE Deſcription of this Piſton, (which is very curious) I give here tranſlated from Monſ. *Belidor*.

Plate 43. *Fig.* 2.

A PISTON without Friction invented by Meſſieurs *Goſſet* and *de la Deuille*, and ſucceſsfully made uſe of in the King of *France*'s Garden at *Paris*.

THIS Piſton may be made as big as you pleaſe, even to have 36 Inches in Diameter, but I ſhall only give 15 to that which I am going to deſcribe, this Bigneſs ſeeming moſt convenient for the Reaſons that will appear as we deſcribe this Piſton. As it is to act in a Pump different from any I have yet deſcrib'd, I will ſhew in what it conſiſts. It is made of two Boards of Oak or Elm, 20 Inches Diameter, and five Inches thick: in the middle of each of theſe Boards, you muſt cut hollow a cylindrick Cavity 15 Inches Diameter, and 2 $\frac{1}{2}$ Inches deep, which forms two Boxes, which muſt be applied to one another with their Hollows together; their Profil taken diametrically is repreſented by each of the Rectangles A B C D and E F H G.

THE Piſton is made of a circular Board Y Z, an Inch thick, whoſe Diameter muſt be a little leſs than that of the Hollow T O Q V, to facilitate its Play: this Board is fix'd to a great Circle of Leather, (or to ſeveral, when one is not ſtrong enough) in ſuch manner that the Leather may extend all round beyond it ſix or ſeven Inches; then you muſt

Lect. XII. muſt put the Board Y Z in the Bottom of the Box S T V X, and what exceeds of the Leather muſt be folded up all round the Edge E 3 X G of the ſame Box. Then you put down the other Box upon the firſt, ſo as to ſqueeze the Leather between; and that it may be preſs'd the more ſtrongly, ſo that the two Boxes may make but one: they are drawn together by means of ſeveral Iron Pins 17, 18, whoſe Ends are cut into Screws, to fit into Nuts; thus the Piſton makes a ſort of a Purſe 3, 4, 5, 6, which turns inſide out every time the Bottom Y Z is drawn upwards.

AT the Bottom of this Purſe there is an Hole L, cover'd with a Valve K, which when it is rais'd comes to lean againſt the Handle M W M, which Handle is faſten'd to the Rod N, that works the Piſton up and down; for doing of which there is another Hole 9, 10, in the Bottom of the upper Box, which anſwers to the riſing Pipe 13, 14, in which the Rod N goes up. This Hole is made ſpreading downwards, that the moveable Board may apply itſelf cloſe to the Top O Q when the Piſton riſes. In the lower Bottom of the Box there is another Hole 19, 20, which anſwers to the Sucking-Pipe 15, 16, that ſtands in the Water to be rais'd; this Hole is cover'd with a Valve I as uſual.

WHEN the Piſton riſes, the Water from the Sucking-Pipe opens the Valve I, and paſſes into the Hollow that is made in an Height of four Inches, which is all the Play that the Piſton ought to have, not to weaken the Leather too much, which would not hold out long if it had too long a Stroke; whereas having at moſt but two Inches and $\frac{1}{2}$ to riſe from 5 to X, it wears but little: when the Piſton comes down, the Valve I ſhuts again, the other K opens, and the Water which is between the Bottom T V, and the Leather 3, 4, 5, 6, goes thro' the Hole L, and comes into the Space O P Y Z Q, whence it is lifted into the riſing, or forcing, Pipe: thus you ſee that the Piſton always moving between the Water above, and that below, has no Friction. I ſhall add, that when it is made of good Leather, it may be continually work'd for three or four Months, without repairing, as Experience has ſhewn it in thoſe Pumps that Meſſieurs *Goſſet* and *de la Deuille* had made for draining the Mines in *Britany*.

THE only Fault to be found with this Piſton, is, that of whatſoever Diameter the riſing Pipe 13 and 14 is, the Power is always loaded with the Weight of a Column of Water, whoſe Baſe is the Circle O Q, and Height the Elevation of the Reſervoir above the Spring; it is true, that one may increaſe the Diameter of that Pipe, and decreaſe that of the Piſton, that when they are equal, the Power may only raiſe its natural Weight.

IT may perhaps be objected, that this Piston having so short a Stroke, will give but a little Water every time; but that is not a Fault, since one may make the Strokes more frequent; so that what may be lost on one hand may be gain'd on the other, and as much Water be rais'd as if the Stroke were longer.

As the Rod of the Piston goes thro' the rising (or Force) Pipe, Water may not be rais'd to a considerable Height by this Pump, yet the Rod of the Pump erected in the King's Garden, is at least 25 Feet long; and if the same Length be given to the Sucking-Pipe, one may however raise Water 50 Feet above its Spring, in a very plain and cheap way. For if you make use of Wood, such a Pump will cost under ten Pistoles; and that, upon many Occasions, where a Pump of great Expence would raise no more Water with the same Power.

SECTION XXI.

HAVING often made these kind of Observations, and communicated with others that made them, I was resolv'd to set one Man to work to raise Water, the most in the least Time, by taking away Friction, which I did in the following manner. I made the Experiment by a Model; but I have since made an Experiment upon the Power, and know the Thing will answer.

Plate 43. *Fig.* 3.

A B C D is a little Room, in whose Floor at K and L M are two Openings, and out at the Side A (from K to A) is a Cistern to receive the Water rais'd, and convey it to the Place where you want it. At K comes up a square Bucket H G, suspended by two Ropes a little above its Center of Gravity at V. At the Bottom of this Bucket is a large Valve, to let it fill itself when it comes down into a Well at W below stairs. The Hook H of this Bucket (when the Bucket is drawn up by its Counterpoise I N N) catches in the Hook K, and empties itself wholly into the Cistern A. When it is empty it is heavier than its Counterpoise, which it brings up to its Place, whilst itself goes down again thro' the Floor P P, to fill itself in the Well W. The Counterpoise to this Bucket is a Trap Door, which makes Part of the upper Floor at L M, but does not come thro' it. This Trap Door, which is here represented by N N near the lower Floor, has an Iron I, from whence a Rope is convey'd over a Roller or Pulley F, whence it is carry'd on to E, and fix'd to some Part of the Circumference of the Wheel E made fast to its Axle, which is at right Angles to the Direction of the Rope. At each End of the Axle there is a Wheel equal to the middle one, with a Rope going down

Lect. XII. down from the Circumference of each of them to hold the Bucket at V; the Axis of this Axle being a Bar of Iron, whose Ends are Pivots of

Plate 43. Fig. 3.

$\frac{1}{2}$ an Inch Diameter turning in Brasses. When the Trap-Door is at L M, and the Bucket is in the Well W, a Man (whose Weight, together with the Trap-Door, is about $\frac{1}{5}$ or $\frac{1}{6}$ more than the Bucket, to have a sufficient Velocity to bring up the Bucket) gets on upon the Trap-Door, and holds by its Iron, standing up a little on one Side to give the Man room to be over the Center of Gravity of the Trap; then immediately the Trap (which has going thro' its Corners four small Iron Guide-Rods like L *o*) and Man go down, while the Rope from I, the Top of the strong Iron, running over the Wheel F, turns the Axis at E by its middle Wheel, while the two Wheels E wind up the Ropes which bring up the Bucket that empties itself into the Cistern A, which the Man below hears when he is come down to the Floor P P, and does not get off from N N his Trap-Door till the Bucket is quite empty. Then he gets off, and runs up stairs as fast as he can to the Floor A B, where he finds his Trap-Door (brought up in the mean time by the Descent of the Bucket) ready to receive him. He gets upon the Trap-Door, and goes down with it again, his Descent being his Time of Rest; and makes his Work of his Return up stairs. N. B. *A Tavern-Drawer, being used to run up and down stairs, is very good for this Work.*

N. B. *The Figure on the right Hand shews this in another View.*

The Pulley-Wheels must be of about 15 Inches Diameter, to avoid Friction.

I tried an Experiment with a Man weighing 160 Pounds, whom I desir'd to go up and down 40 Steps of 6 $\frac{1}{2}$ Inches each, (in all about 22 Feet) at the same rate that he could go up and down stairs all Day. He went up and down twice in a Minute. Therefore if the Bucket with a Quarter of a Hogshead in it weighs 140 Pounds, he is able to raise it up 22 Feet high twice in a Minute; consequently Half a Hogshead 22 Feet once in a Minute; and therefore a whole Hogshead 11 Feet in a Minute ——— A little more than my *Maximum* by the Quicksilver Engine. But in reality the Height was but 10,5 Feet, because there were but 39 Steps, which I first call'd 40, to avoid Fractions.

Section XXII.

When different Phænomena, examin'd differently, come at last to agree in the Conclusion, it is a sign that we have discover'd the Truth.

A plain Instance of it will be given here, by examining what a Man can lift continually of dry Weights, with what we have been observing that

Plate. XLIII.
front.^{g} p. 504.

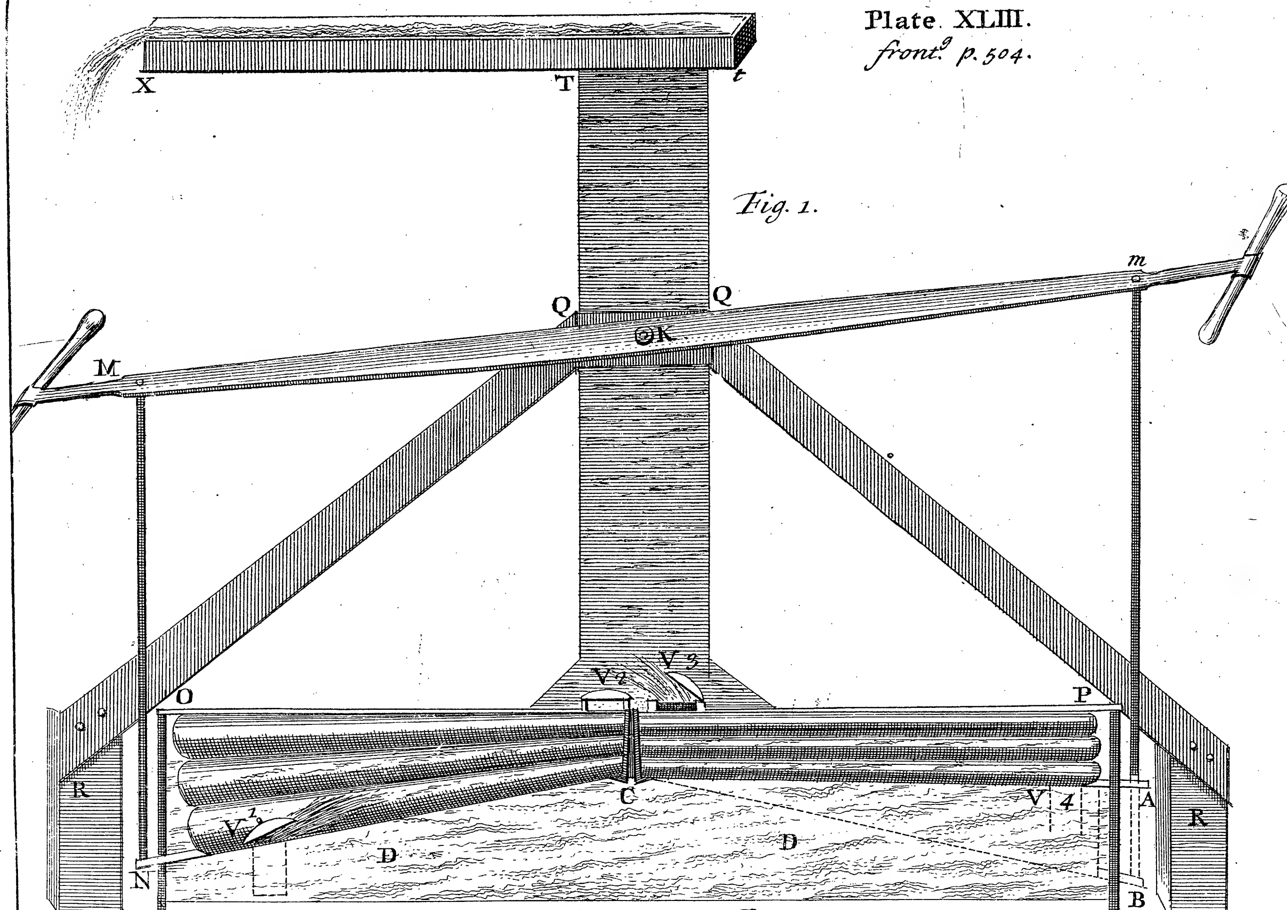


Fig. 1.

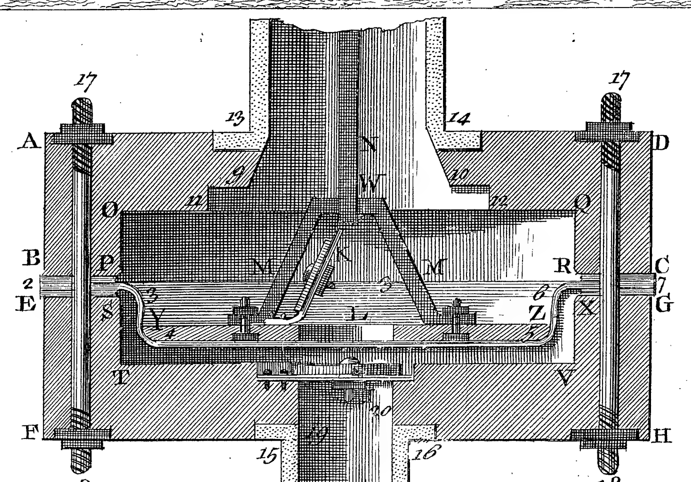


Fig. 2.

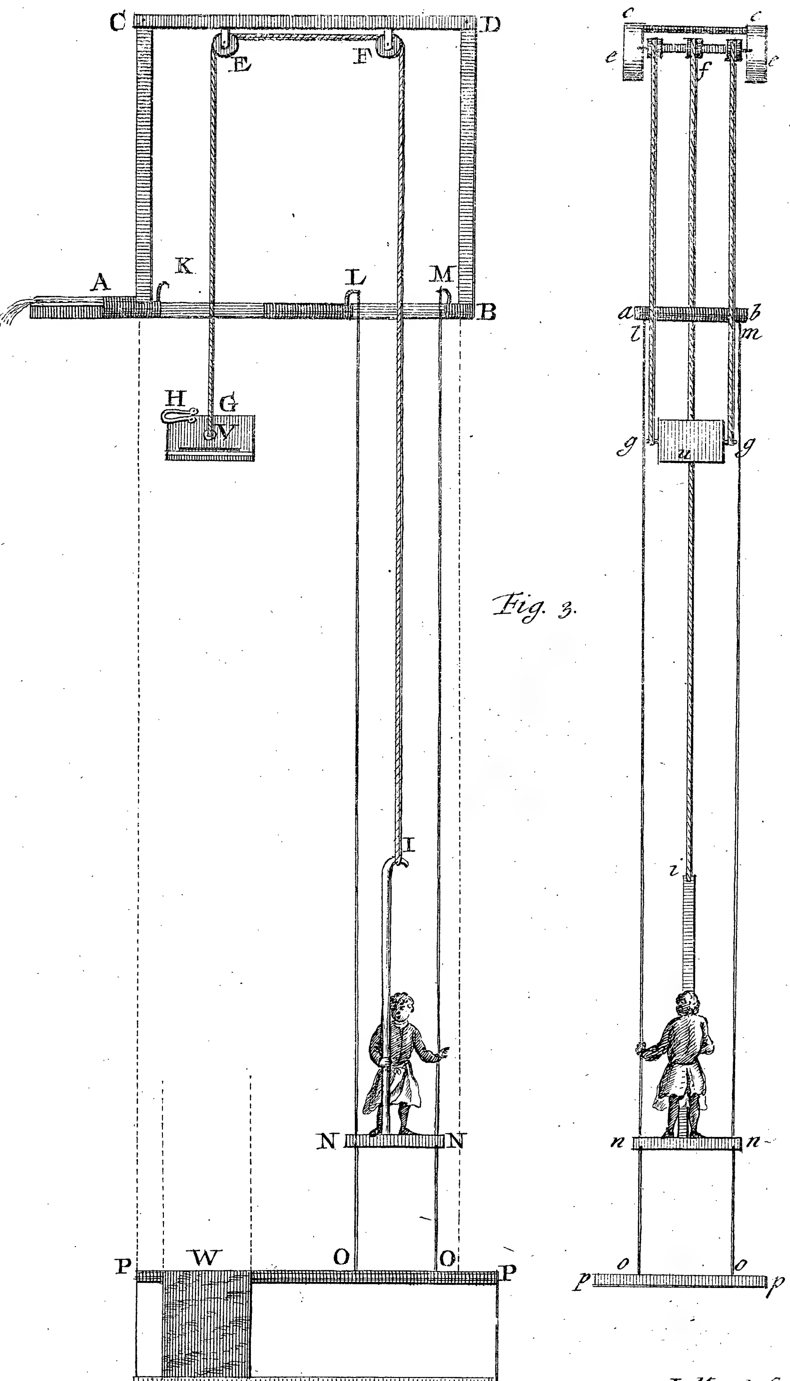


Fig. 3.

J. Mynde sc.

that he can lift of Water, when the Water-Engines are ſo good and ſimple that there are but very few Parts to cauſe any Friction: and we ſhall find the two *Maximums* to agree. Lect. XII.

LET there be a Winch or Windlaſs, whoſe Handle is 14 Inches long, and that the Barrel or wooden Axle be ſo ſwell'd up with Pieces put on, as to make the Circumference of it equal to the Circle deſcrib'd by the End of the Handle where the Man applies his Hand. If a certain Weight, for Example 30 ℔. be fix'd by a Rope to this new Circumference of Barrel, the Man's Hand moves with the ſame Velocity as the Weight. Now it is found by Experience, that a Man cannot long work if he has 30 ℔. to raiſe; but will for ſix or eight Hours very well raiſe 25 Pounds. Let us examine this further.

SINCE the Handle is fourteen Inches long, the Man deſcribes a Circle whoſe Diameter is 28 Inches, and therefore its Circumference is 88 Inches. This Handle is turn'd round 30 times in a Minute, (or once in two Seconds.) Thirty times 88 is = 2640 Inches equal to 220, the Length gone by the 30 Pound in one Minute.
Then half that Length (110 Feet) will be gone thro' with 60 ℔. in 1′.
A quarter of that Length (55 Feet) will be gone thro' with 120 ℔. in 1′.
An eighth of that Length (27,5 Feet) will be gone thro' with 240 ℔. in 1′.
$\frac{1}{16}$, or (13,75 Feet) will be gone thro' with 480 ℔. in 1′.

BUT by this Analogy, 10 : 480 : : 13,77 : 660
660 Pounds (a little more than one Hogſhead) will come up 10 Feet in a Minute: when a Man is ſuppos'd to raiſe 30 Pounds.

BUT as 30 : is to 25 : : ſo will 660 ℔. be to 550 ℔. about the Weight of one Hogſhead.

THE late Mr. *Richard Newſham*'s Engine for putting out Fires is the laſt I ſhall entertain my Reader with. I had the Draughts and Deſcription from Mr. *de Labelye*.

Notwithſtanding its Merit, it does not come up to my Maximum *for Quantity of Water; but it ought not to do it, as I ſhall ſhew in the Notes* *.

* Ann. 8.

A Deſcription of the late Mr. Richard Newſham's *Engines to put out accidental Fires.*

I THINK I cannot conclude this Chapter of Machines better than by giving the Deſcription of an Engine for quenching Fires, as they are now made in a very ſtrong, well-contriv'd, and workman-like manner, by Mr. *Richard Newſham*, Engine-maker, living in *Cloth-Fair* near *Smithfield*, *London*.

Lect. XII. Plate 44. Fig. 1.

THE following Description contained in the Explication of the following 11 Figures was drawn up, the perspective View, and all the chief Parts of the Engine carefully measur'd, and laid down from proper Scales, at my Desire, by Mr. *Charles Labelye*, formerly my Disciple and my Assistant, and since that Time appointed Engineer of the Works of *Westminster*-Bridge by the Right Honourable, *&c.* the Commissioners appointed by Act of Parliament for building the said Bridge.

Fig. 1. represents a perspective View of the whole Engine ready for working, as it appears to an Eye seven Feet high above the Ground, and at six Feet Distance from the nearest Corner of the Engine thro' a vertical transparent Plane, that should be plac'd close to the said Engine, and suppos'd equally inclin'd (*viz.* at an Angle of 45 *deg.*) to the right Side, and to the hind Part of it.

IT appears at first View, (and still more plainly, if this first Figure is compared with Figure 2. which represents a Plan of the Engine) that it consists of a Cistern about three times as long as it is broad: This Cistern, which is to contain Water, is made of old well-season'd *English* Oaken Planks near two Inches in Thickness, strongly fastened and framed together, and its Joints lined with Sheet Copper, and easily moveable, by means of a Pole and cross Bar, (which appears in this View drawn out, at the furthest End, which is the fore part of the Engine) and of four solid Wheels, which shall be more fully describ'd hereafter. Upon the Ground next to the hind part of the Engine may be seen a Leathern Pipe of about two Inches Diameter, the End of which may be screw'd on and off upon occasion, at the lower End of the Cistern, to a Brass Cock, which shall be describ'd at large. The Use of this Pipe is, that when Water is to be had near the Place where the Engine is to work, such as a Pond, a Kennel, or a Fire-Plug, the lower End of this leathern Pipe being immers'd in the Water, it becomes a Sucking-Pipe, which furnishes the Pumps of the Engine by its working, without any necessity of pouring Water into the Cistern.

OVER the upper End of this Pipe may be seen a wooden Trough fasten'd to the hind Part of the Cistern, with a Copper Grate that keeps Stones, Sand, and Dirt out, but lets into the Cistern the Water that is brought for the use of the Engine, when the Sucking-Pipe cannot be used. The fore Part of the Cistern is also separated from the rest of its Cavity by another Copper Grate, as may best be seen in Figure 2. and serves as another Trough, in which, as well as in the last-mention'd Trough, the People who supply the Engine with Water, can pour it, without any Hindrance to those who work the Engine at the long Sides, by moving the Handles which work the Pumps up and down, in which

Work

Work they are greatly aſſiſted by three or four People, who at that Lect.XII. time get up upon the Engine, and ſtanding upon two ſuſpended Treddles throw their Weight alternately upon each of theſe Treddles, keeping themſelves ſteady by laying their Hands, or taking hold of two round horizontal Rails, that are framed for that purpoſe into four vertical Stands made of two Inch Planks, which reach to the Bottom of the Ciſtern, and are well faſten'd to its Sides, as plainly appears in this perſpective View.

CLOSE to the hind Trough may be ſeen an Iron Handle or Key, which ſerves to open and ſhut a Cock placed under it, on the Bottom of the Ciſtern. The Uſe and Contrivance of this Cock ſhall be deſcribed hereafter. Next to this Cock, and right under the Point of Sight of this perſpective Draught, may be ſeen a ſort of an inverted pyramidal Box or Caſe; the Uſe of which, in the firſt place, is to preſerve the two Pumps and the Air-Veſſel from Duſt or Dirt, when the Engine is laid by, which if left open, would thereby ſoon be out of order; it ſerves alſo to ſupport a wooden Frame near two Feet ſquare, on which ſtands a Man, who by turning the Spout, and raiſing or depreſſing it, directs the Stream towards the Places where it appears to be moſt wanted. This Spout is made of two Pieces of Braſs Pipe, each of them having an Elbow, as may be ſeen in this Figure. The lower of the two is ſcrew'd over the Neck, or upper End of the Pipe that goes thro' the Air-Veſſel, and the upper Part of this Spout ſcrews on to the lower by a Screw of a pretty many Threads, ſo truly turn'd as to be Water-tight, without any help, in every Situation.

ON the hindmoſt Side of this Encloſure may be obſerv'd a little Flap or Door, which opens by raiſing it round the two Braſs Hinges at top; when lifted, it diſcovers a Leaf of tranſparent Horn that covers a printed Paper, which Mr. *Newſham* generally annexes to each of his Engines, containing proper Directions how to uſe and keep them in good Order. This Leaf of Horn is very prudently ſubſtituted for a Pane of Glaſs, which would be in great danger of breaking by the ſhaking of the Engine, when it is drawn upon paved Stones, or rough uneven Ground.

BEHIND this truncated pyramidal Encloſure may be obſerv'd a ſtrong Iron Bar lying in an horizontal Poſition over the middle of the Ciſtern: This Bar plays in *Braſſes* properly faſten'd and ſupported by two wooden Stands, one only of which is to be ſeen in this Perſpective View, placed between the two fore Stands of the upper Rails: The other Stand, on which it is ſupported, is hid in the Encloſure over the hind Part. Upon proper Squares of this Bar are fitted (one near each End)

Lect. XII. Plate 44 and 45. two ſtrong croſs Bars, which embrace or take hold of the long wooden cylindrical Handles, to which the Men employ'd to work the Engine apply their Strengths very advantageouſly, their Stroke not reaching higher than their Neck, nor lower than their Thighs, (as it ought to be in that way of working) and in which they are greatly aſſiſted, as was ſaid before, by the Men who work the Treddles.

THESE Treddles are ſuſpended at each End by Chains made like a Watch-Chain, every Link about two Inches long, and of a ſufficient Strength and Thickneſs; theſe Treddles receive their Motion jointly with the Handles that are of the ſame ſide, by means of two circular Sectors of Iron faſten'd together, and fix'd upon proper Squares of the middle horizontal Bar: the two fore ones may be plainly ſeen in this perſpective Draught; but the two hind ones are hid by the Encloſure already mention'd. Theſe hind Pair of Sectors are the ſame in Size and Figure as the two fore ones, excepting as to their Thickneſs, for the fore ones are made to carry only one Chain each, one End of which is faſten'd to their upper Part, and the lower End is faſten'd to the Treddles; but the Sole of the two hind Sectors are made wide enough to carry two Chains each; one Set is faſten'd as the fore ones for the Motion of the Treddles, but the other two Chains are faſten'd by their lower Ends to the lower Part of theſe Sectors, and by their upper Ends to the Top of the Piſton Bars, to give them Motion, which is repreſented at large in *Fig.* 6.

As I am going to deſcribe the principal Parts at large, it is ſufficient to add to the general Deſcription of this Engine, and the Explication of this perſpective View of it in *Fig.* 1. that the Pole and croſs Piece, which is ſeen in the fore Part, and fartheſt from the Eye, are ſo contriv'd as to ſlide back under the Cover of the Ciſtern, when the Engine is brought where it is to work, and to remain there out of the way of the People that bring Water to the fore Part of the Engine, (the whole Engine being made to ſtand in a very narrow Compaſs) and yet is ready to be drawn out as it is repreſented, whenever there is occaſion to move the Engine.

Fig. 2. repreſents the Plan of the ſaid Engine, or rather an horizontal Section of it taken juſt above the Bottom of the Ciſtern——But before I proceed further, it is proper to obſerve, that to avoid the inſerting every where the Dimenſions of the Parts, (in order to give a true Idea of them) the *Figures* 2d, 3d, 4th, and 5th, are carefully laid down from the leſſer of the two Scales; and the reſt of the *Figures*, *viz.* 6th, 7th, 8th, 9th, 10th, and 11th, are as carefully laid down from the larger Scale, the better to ſhew them from, and to enable the Readers to meaſure any of the Parts.

To

To proceed now, the Letter A (ſee *Fig.* 2.) ſhews the fore Part of the Ciſtern, which is ſeparated, to ſerve as a Trough, from the reſt of its Cavity, by a Copper Grate repreſented by ſhort vertical Strokes. Lect. XII. Plate 44.

B is placed behind the hind Part of the Ciſtern, and is in the middle of the hind Trough.

C, D, E, F, ſhaded with horizontal Strokes, repreſent the lower Plan or Section of the four Stands which ſupport the Hand-Rails.

G H and I K, ſhaded alſo with horizontal Strokes, repreſent ſo much of the two Axle-Trees as can be ſeen from above; the hind one I K is faſten'd acroſs under the Bottom of the Ciſtern, but the fore Axle-Tree G H is put on a ſtrong Pin or Bolt N, ſtrongly faſten'd in an horizontal Situation in the middle of the Front of the Bottom of the Ciſtern, by which good Contrivance the two fore Wheels and their Axle-Tree have (when neceſſary) a circular Motion round the Bolt N; which affords this great Conveniency to the Engine, that it ſtands as firm and ſteady on rough, uneven, or even ſloping Ground, as if it was level.

L and M, ſhaded with vertical Strokes, repreſent the Section or lower Plan of the two Stands, on which the middle Bar plays in Braſſes; theſe two Stands (for greater Steadineſs) are ſtrongly faſten'd at their Tops by Iron Bars that go thro' the two Stands, (already deſcribed) between which each of theſe is placed, as may be ſeen in the perſpective View, *Fig.* 1.

O, P, Q, ſhaded with horizontal Strokes, repreſent the Plan and the Shape of a ſtrong Piece of caſt Braſs, (or rather hard Metal) about three Inches thick, ſo work'd as to have a Hollow of about two Inches ſquare, near one End of which is adapted the Cock Q. At ſome diſtance from this Cock the Hollow branches itſelf into two, as may be ſeen by the faint Lines in this Figure, and opens on the upper Surface of this Piece juſt under the Places where the Valves of the Pumps are put. This Piece of Metal lies flat upon the Bottom of the Ciſtern, to which it is ſtrongly fixed in the Situation repreſented by this Figure. It may be call'd the *Sucking-Piece*, thro' which Water is convey'd to the Pumps by the Preſſure of the Atmoſphere, either from the Ciſtern itſelf when the Cock Q is turned in a certain Situation, or from any Water at a diſtance by means of a leathern Pipe, (which ſcrews on to the Sucking-Piece at B under the hind Trough) when the Cock is turned in another certain Situation. All that remains to be explain'd in this Figure is, that between P, O, and Q there is a Circle of Dotts which repreſents the middle Section, and the Situation of an Air-Veſſel, of which I ſhall ſpeak preſently, and to obſerve that the Top of this Ciſtern is ſtrengthen'd

by

Lect. XII. by one, two, or three *Tranſoms* or croſs Pieces about two Inches thick, according to the Size of the Engine; there are three repreſented in this Figure, one between C and D, another on which is the Letter M, and a third between theſe two.

Plate 44 and 45.

Fig. 3. repreſents the upper Plan, and the Shape of another Piece of caſt Braſs or hard Metal, about 3 Inches thick, having two Hollows marked in faint Lines, near two Inches ſquare, which open two Communications from the Holes O and P, to two other Holes in the upper Surface at R and S, over which is placed the Air-Veſſel.

When the Engine is together, this Piece, which may properly enough be called the *Communication-Piece*, is placed exactly over the ſucking Piece O P Q, to which it is ſtrongly faſtened by ſeveral Screws, in ſuch manner that the Parts marked with the ſame Letters O and P in this and the 2d Figure, are exactly one over the other; and the Holes mark'd R and S in this 3d Figure, are exactly over the Diameter of the Circle of Dotts in *Fig.* 2. Between the Sucking-Piece, repreſented in *Fig.* 2. and the Communication-Piece, repreſented in this 3d *Fig.* are placed two Plates of Ox-Leather, in order to make the two Pieces water-tight; and theſe two Plates of Leather are ſo contrived as to form the two ſucking Valves over the Holes O and P, as ſhall be explained hereafter.

Fig. 4. repreſents the Shape of the Braſs-Flanch to which the Air-Veſſel is ſoldered; when the Engine is together, the Holes R and S of this Flanch are exactly over the Holes R and S in the Communication-Piece, repreſented in the 3d Figure; to which it is alſo ſtrongly faſtened with ſeveral Screws. Between the laſt-mentioned communicating Piece and this Flanch of the Air-Veſſel are placed two other Plates of Ox-Leather, which form the 2 Valves of the Air-Veſſels, as ſhall be better ſhewn when I come to explain the Sections of this Engine.

Fig. 5*th*. repreſents the Elevation and outward Shape of a large Copper Air-Veſſel, which receives the Water forced into it by the Action of 2 Pumps, thro' the 2 Holes in its lower Flanch; the Letter T ſhews the Top of a Copper-Pipe within the Air-Veſſel, and ſoldered to its upper Neck, which reaches within a few Inches of the Bottom. When the Engine works, the Water is forced in a conſtant Stream, and almoſt uniform as to its Velocity thro' this Pipe and the Spout or Leather-Pipe which is ſcrewed to it at T, by the Action of the Forcers in the 2 Barrels and the Re-action of the Air contained in the Air-Veſſel; which Air-Veſſel being very large in theſe Engines, renders the Stream much more uniform than in thoſe that have either ſmall Air-Veſſels only, or none at all; which Sort of Engines throwing the Water by *Spirts*, are commonly, and not improperly called *Squirting* Engines: however, in ſome caſes, theſe have

have their Use, on account of their Stream (though, interrupted) being much smarter than when the Engine is made to throw the Water in a constant Stream. Lect. XII. Plate 44 and 45.

Fig. 6. represents the two hind Iron Sectors laid down from a larger Scale, and all their Apparatus, as they would appear to a Person standing between the two Fore-Wheels, and looking from thence at the hind-part of the Engine. The Square over the Letter A, represents the Section of the middle Bar, on which, right over the two Barrels, are placed the two Sectors BCA and DEA forged together.

FGHK, and its opposite *fghk*, represent the Figure of the two Piston Rods. The Openings between the Letters GH and *gh*, are the Places thro' which pass the hind Parts of the two Treddles.

L and M represent two strong Iron *Studs*, riveted on the other side of the Bars on which they are placed : To each of these *Studs* is fastned a Chain like a Watch-Chain, the upper Ends of which are fastened to the upper Extremities D and B of the Iron Sectors, by which they are drawn up and down alternately. These Sectors give also an alternate Motion up and down to the Piston-Rods, by means of two other Chains (left white in this Figure for Distinction-sake;) the lower Ends of these two Chains are fastened to the lower Extremities of the Sectors E and *e*, and their last Links at their upper Ends are made like a Piece of a square Bar of Iron about 2 or 3 Inches long, each ending in a Male-Screw, which goes thro' the upper Ends of the Piston-Rods (made crooked on purpose,) and the whole made tight by the 2 Nuts at F and *f*. It must be carefully observed, that the Shape of the Piston-Rods and the Size and Situation of the Chains whence they receive their Motion, is so well considered, that the Axis or middle vertical Line of the Pistons is exactly in the middle of the Breadth of the perpendicular Part of the Chains, and of the upper Part of the Piston-Rods taken together.

PQ represents one of the two Cross-Bars, thro' the Ends of which go the long Handles to which the Men apply their Hands when they work the Engine; these Cross-Bars are also fitted on the middle Bar (whose Section is mark'd over the Letter A) but at some distance from the Sectors, as will best appear in the Sections. The Sectors placed on the fore-end of the middle Bar, are of the same Size and Shape as these, but not so thick, because they carry only one Set of Chains to give motion to the other End of the Treddles.

Fig. 7. represents a vertical Section taken thro' the middle Line of the hind-part of the Engine, as also the Section of the Air-Vessel, and that of one of the Barrels, as also the Profils of the hind Sectors, and of several other Parts.

Lect. XII. Plate 44 and 45.

AB is the Section of the Bottom of the Ciſtern, under which at C may be ſeen the Section of the hindmoſt Axle-Tree faſtened under that Bottom.

DE is the vertical Section of the ſucking Piece, whoſe Plan is repreſented from a leſſer Scale, in *Fig.* 2. The hollow Part left white, reaches from the Opening D thro' the Cock W, and afterwards divides it ſelf, as may be ſeen in *Fig.* 2. ſo as to open under the two Barrels; one only of which is repreſented in this Section, the other being exactly behind this.

FG repreſents the vertical Section of the Communication-Piece, whoſe Plan is alſo repreſented from a leſſer Scale, in *Fig.* 3. There are two Hollows in this Piece, which conveys the Water from under the two Piſtons to the two Openings of the Flanch of the Air-Veſſel; but only one of theſe Hollows can be repreſented in this Section, the other lying exactly beyond this, tho' not in a parallel Direction, as may be ſeen in *Fig.* 3. Between the Section of the Sucking-Piece DE, and that of the Communication-Piece FG, may be obſerved the Section of one of the Plates of Leather, which makes all tight, and forms one of the two ſucking Valves, of which there is another juſt behind this under the other Barrel.

RST is the Section of the Air-Veſſel, and TV is the Section of the Conduit-Pipe; this Veſſel is ſcrew'd on the hind-part of the Communication-Piece, and is alſo faſtened at top by a Collar of Iron, and ſcrews to a croſs Piece of Timber not repreſented in this Section. Between the Flanch of the Air-Veſſel and the Communication-Piece may alſo be obſerved the Section of one of the Plates of Leather which makes all tight, and forms one of the two forcing Valves, of which there is another juſt behind this, juſt over the other Opening of the Communication-Piece into the Air-Veſſel.

HI is the Section of one of the Barrels of the two Pumps, which are both ſucking and forcing, as is evident from the Poſition of the Valves, and the Structure of its Piſtons; each of which is compoſed of two Iron Plates, of two wooden Trenchers, and of two flat Pieces of Leather turning one up and the other down. One of the Methods of entering this Piſton into its Barrel may be as follows: Firſt put on the lower End of the Piſton-Rod the upper one of the Iron-Plates cloſe to a Shoulder forged there on purpoſe, as may be ſeen in *Fig.* 6. Then put on the upper wooden Trencher, cloſe to the Iron Plate; and next to that, put on the upper Piece of Leather broad enough all round to turn up, as in the Figure; then enter the Piſton-Bar (thus far equipt) into the upper End of the Barrel to which it belongs, and force it down ſo far thro' it, as to be able to put on at the other End of the open Barrel the lower Piece of Leather entirely ſimilar to the upper one, cloſe to that upper one; then the

the lower wooden Trencher cloſe to the lower Piece of Leather, and cloſe to this lower wooden Trencher, put on the lower Iron Plate, and then ſecure the whole by means of an Iron Nut which ſcrews on the lower End of the Piſton-Bar, as may be ſeen in *Fig.* 6. After which the Piſton-Rod being drawn up, ſo as the whole Piſton be within the cylindrical Cavity of the Barrel, the lower Plate of Leather will be forced to bend downward all round, and the upper one to bend upwards all round; and then the Barrels being ſcrewed in their Places, will be in a working Order. Lect. XII. Plate 44, & 45.

L K repreſents one of the Piſton-Rods edgewiſe, as it muſt appear in this Section; behind which is one of the Chains (which except the Top Screw K cannot be ſeen in this Figure;) this Chain is the ſame as one of thoſe left white, in *Fig.* 6. mark'd *f g h k*.

M repreſents the End of the middle Bar, which communicates from this hind-part to the fore Sectors; it plays on Braſſes; the Section of the one of which is repreſented in this *Fig.* ſhaded with vertical Strokes between the Letter M and the Letter N; which Letter N repreſents the Section of the hindmoſt of the two middle Stands, which ſupport the middle Bar.

O repreſents the End of the Profil of one of the Treddles, going thro' the Piſton-Rods in rectangular Holes, to be ſeen in *Fig.* 6. The Weight of the People that ſtand on theſe Treddles when the Engine works, brings them and the Piſton-Rods down alternately, and they are raiſed up again by help of the other Set of Chains, one of which may be ſeen edgewiſe in this Figure, placed on the *Sole* of one of the Sectors, and faſtened by its lower Extremity to a ſtrong Iron Stud, already deſcribed in explaining *Fig.* 6. whoſe Profil may alſo be ſeen in this Figure juſt above the Profil of the Treddle.

P Q is part of one of the Croſs-Bars (which carry the Handles) ſeen edgewiſe, which ſhew how they are faſtened on the middle Bar.

X Y repreſents an Iron Handle, by the help of which the Cock W may be placed in the ſeveral Situations which are neceſſary for the Service of the Engine, as I ſhall explain preſently after.

Laſtly, ROUND the Letter Z may be ſeen the Section of the Hind-Troughs, in which Water being poured, it enters the Cavity of the Ciſtern (leaving Sand, Dirt, and Stones in the Trough) thro' a Copper-Grate, the Section of which is repreſented in this Figure ſhaded with horizontal Strokes.

Fig. 8. REPRESENTS the Plan of one of the Valves, for example, one of thoſe which are placed under the Flanch of the Air-Veſſel; it is made (as was ſaid before) of a Plate of Leather cut out, as is repreſented in this

 Figure

Lect. XII. Figure ſhaded with horizontal Strokes, the Flexibility of the Leather (eſpecially when wetted) in that part of the inner Circle of the Valve by which the Flap of it joins the reſt of the Leather, affords a very cheap, Plate 44, & 45. proper, and ſufficient Hinge for the Motion of the Valve up and down.

The Top of the Flap of this Valve is loaded (in order to make it ſhut the cloſer) with a *Lump* of caſt Iron, or Lead, having a *Tail* or *Teat* projecting from its under Surface, which is let thro' the Flap of the Valve, and croſs-pinned under it; the upper Surface of this *Lump* is ſeen in this Figure, ſhaded with vertical Strokes; and the Section of the ſaid *Lump*, with that of its *Tail* or *Teat*, and Croſs-Pin, may be ſeen in *Fig.* 7. Whereupon it is to be obſerved, that in *Fig.* 7. both the Valves have been repreſented open (the better to ſhew their Shape and Situation) tho' they are never both open; for when the Engine is not at work, they are both ſhut down by the Weight of the Lumps on their Tops; and when the Engine works, there are always two of them ſhut, and the other two open alternately, by the Motion of the Piſtons and the Action of the Atmoſphere, with the Re-action of the Air confined in the Air-Veſſel.

The 9th, 10th, and 11th Figures repreſent the Section of the ſame Cock W, (which has three Holes in it left white or unſhaded in theſe Figures) in the three different Situations which I am going to explain. *Fig.* 9. repreſents the horizontal Section of the Cock, when the Handle is as in the Situation repreſented in *Fig.* 7. or in the perſpective Draught, *Fig.* 1. that is, when this Handle lies in a Direction parallel to the Piece DE or to the middle Bar, the Handle is ſo placed when there is Water near at hand to work the Engine by help of the ſucking Leather-Pipe, repreſented in the firſt Figure; in which caſe it plainly appears, that the Water entering at D proceeds (directly thro' the Cock W) in a ſtreight Line to the Valve under the two Piſtons; and in this Poſition, there is no communication from the Barrels with the Cavity of the Ciſtern.

Fig. 10. Repreſents the horizontal Section of the ſame Cock W, when the Handle (XY in *Fig.* 7.) is turned one quarter of a Revolution towards the Eye from the laſt-mentioned Situation, in which caſe there is no communication from the Barrels with the outer Extremity of the ſucking Piece, but the Water that is poured in the fore and hind Trough (when none is to be had without fetching it from farther than the Leathern ſucking Pipe will reach) paſſing from thence in the Cavity of the Ciſtern, enters the Cock ſidewiſe at W, in this Figure, and turning at Right Angles thro' the Cock towards E, proceeds to the Barrels of the Pumps.

The 11th *Fig.* repreſents the horizontal Section of the ſame Cock W, when the Handle is placed in a Situation diametrically oppoſite to that of

of which I have been laſt ſpeaking. In this Situation of the Cock, there is no communication from the under-ſide of the Barrels, with the Cavity of the Ciſtern or the outward End of the ſucking Piece; but this Situation affords a Communication from the Cavity of the Ciſtern with the outſide of the Engine; the Cock is commonly placed in this Situation when the Engine has done working, to employ the Water left in the Cavity of the Ciſtern. Lect. XII.

BEFORE I conclude the Deſcription of this uſeful Engine, I muſt obſerve that there are 5 or 6 Sorts or Sizes of them, and that even the largeſt of them (all ready for working) can paſs thro' a Door or Paſſage ſomething leſs than 3 Foot wide, which is a Conveniency and Advantage peculiar to it, which is very well worth obſerving; and that having examined the Conſtruction and Operations of the ſeveral Parts of many of theſe Engines, it is my humble Opinion that nothing can be altered in them for the better.——The Engine here deſcribed is one of the ſecond Size, or of that Size next to the largeſt. But to ſhew a compariſon of them all, here follows a Table which is taken from Mr. *Newſham*'s (the Maker's) printed Papers, given away to his Friends.

HOW many Men may be applied to each Engine, and leave ſufficient room to pour in Water: *Which is a Convenience of great advantage; tho' any Number can work them to* more *purpoſe, than they are* able *to work* any other *ſort.*

The firſt Size	8	4*th.*	18
2*d.*	14	5*th.*	22
3*d.*	16	6*th.*	24
1*ſt* Garden Engine	2		
2*d* Garden Engine	4		
Hand Engine	1, *but is of a different Make.*		

Lect. XII.

How much Water the Ciſterns hold in Gallons: Wine-Meaſure.	How many Gallons diſcharged *per* Minute.	At what Number of Yards diſtant.
1*ſt*, 50 4*th*, 146	1*ſt*, 70 4*th*, 150	1*ſt*, 37 4*th*, 48
2*d*, 100 5*th*, 176	2*d*, 100 5*th*, 170	2*d*, 40 5*th*, 50
3*d*, 120 6*th*, 196	3*d*, 120 6*th*, 200	3*d*, 45 6*th*, 52
1*ſt* Garden Engine 20	1*ſt* Garden Engine 30	1*ſt* Garden Engine 25
2*d* Garden Engine 30	2*d* Garden Engine 50	2*d* Garden Engine 33
The Hand Engine 12	The Hand Engine 25	The Hand Engine 15

An Account of Ten Conveniencies *peculiar to Mr.* NEWSHAM's Engines.

I. HIS Engines, by a new Contrivance in the fore Axles, will ſtand upon any uneven Ground without rocking, even when the full Number of Men are at work in Extremity.

II. THEIR Carriage-Wheels are never to be bolted, and yet the Engine ſtands firm, without moving backwards and forwards whilſt it is playing a continued Stream of Water at Fires.

III. THEY are fixed to Crank Axles; by which Improvement the Engine runs upon larger Wheels, without raiſing the Ciſtern above the power of the Men who work it, and is leſs liable to be overturned, in running along the Streets.

IV. THESE Engines are ſo contrived, that the largeſt may be inſtantly turned about any way, in the compaſs it ſtands in, by one Man, tho' half full of Water.

V. THE largeſt will ſtand on a Space of one Yard in Breadth, and in compleat working Order, ſo that Carts may paſs and repaſs: But another Kind of large Engine that is wrought at the Ends of the Ciſtern when fix'd for working (without any Men) takes up nine or ten Feet ſquare: So conſequently leaves no room in narrow Streets for Carts to carry off Goods in danger.

VI. HIS Engines are provided with his new-invented Cock, which, with a quarter Turn, opens one Paſſage, and ſhuts another, which is the cauſe of Suction, or playing out of the Ciſtern, as occaſion requires; this Turn may at any time be made whilſt the Men are at work, and ſo quick, that no Variation can be obſerved in the Stream; and what is extraordinary, the Engine by this Cock ſupplies itſelf with Water, and plays a cloſe and continued Stream, although no Water be in the Ciſtern.

VII.

VII. THE Staves which the Men work by, are always fixed, ſo that nothing is to be taken out or put in; but the Engine is in immediate readineſs, either to work or move out of danger; alſo the Staves and Leavers are very light, as alternate Motions with quick Returns require; yet, will not ſpring and loſe time in the leaſt; but the Leavers and Staves of ſuch Engines as are wrought at the Ends of the Ciſterns, are not only heavy, but will ſpring or break, if they be of ſuch a length as is neceſſary for a large Engine, when a ſufficient Power is apply'd; and cannot be fix'd, becauſe they muſt at all times be taken out (tho' 14 Feet of Room is required for it) or have an Alteration equivalent, before that Engine can go through a Paſſage. Lect. XII.

VIII. THAT the Men may hold it working a long time together without reſting, he has contriv'd Conveniencies for many Men to work at each of the 3d, 4th, 5th, or 6th ſiz'd Engines, which do alſo augment their Performances. Thus 24 Men can work at one of his largeſt (tho' not nine Feet long) with equal Power and Advantage, by Hands and Feet jointly, or at pleaſure with eighteen by Hands only, and leave room to pour in ſix Buckets of Water at a time, (which drains through large Copper Strainers.) This Conveniency is abſolutely neceſſary where Suction cannot be had: But is entirely wanting in Engines that work at the Ends of the Ciſterns, becauſe they cannot allow Water to be pour'd in, whilſt a ſufficient Number of Men are at work.

IX. THE Forcers of his Engines, by contrivance of a Wheel and riveted Chains, (ſtrong enough to hold three times the Strain that can ever be given them) make a perpendicular Stroke, which produces a more even and cloſe Stream, and is one cauſe of throwing more Water to the End thereof; alſo occaſions leſs Friction, and wearing of the Forcers; and by means of this perpendicular Motion (with the ſame purchaſe, in the ſame time, and with the like power apply'd to his Engines, as to thoſe whoſe Forcers do not move perpendicularly) he makes a longer, and a more effectual Stroke: Whereas the Leavers in other Engines, which give the Motion to their Forcers, by deſcribing an Arch, cauſe them to move in the Barrels with an unequal Velocity, being quickeſt, and hardeſt to work at the middle of the Stroke, juſt where the Men have the leaſt operating Power to apply.

X. HIS large Engines may be play'd by Suction; with nine or ten Men in a Paſſage, three Foot and an half wide, or with ſeven or eight Men, and leave room to pour in Water by three Buckets at a time: Neither of which can be done with Engines that work at the Ends of the Ciſterns, becauſe their Sucking-Pipes are ſcrew'd upon the Sides of the Engines; and having Hoops within to keep them open, they require

more

Lect. XII. more room than a narrow Passage will allow; and as the Men are to stand at the Ends of the Cisterns, they must of consequence take up all the room in such a Passage, so that it will be impossible to pour in Water whilst they are at work. And no Engines are less liable to disorder than these; nor so easily repair'd. *Yet particular Directions in Print to render it more easy, are durably fixed unto them.*

THERE is a mistake very common among such as are not well acquainted with the Laws of Nature, and the Effects of mechanical Powers, who imagine, that the more Purchase the Leavers have upon the Forcers in the Barrels (without any regard to Time) the greater the Performance, both as to Length of the Stream, and Quantity of Water delivered; but 'tis well known that Notion is wrong, for the greater the Purchase is, by applying the operative Power, more distant from the Center, the slower will the Motion of the Forcers be; which is consistent with all mechanical Effects; so, what is thus gained in Force by the Power, is lost in Time.

NOW, for an Inventer to have his Works invadingly imitated, or to have his useful Inventions fallaciously reason'd against, is a great Hardship, and such pyratical Injuries do often occasion some hurtful Events, and can no ways be profitable to *any:* not to the invading *Operator*; because, (Price for Price) *he* cannot *of a long time, and with a vast expence,* afford to equal these Engines; either in respect to the Value of Materials put in them, or in the Goodness of Workmanship and their Performances: Therefore the BUYER is consequently deceived, by reason of these unseen Deficiencies, &c. and likewise, it here may be duly observed; *that the common unhappy Fate, of lessening both Substance and Credit,* is usually found in such pernicious and hazardous Attempts: As to vie with one so well skill'd in his Inventions; by a long Experience therein; which is the means of knowing all the best Methods of proceeding in every Branch of the same; both for himself *and a* PUBLICK *Good.* So upon the whole, he leaves it to the impartial World to judge whether the Man who finds out useful Inventions (and vends the same for a moderate Gain) or he who only steals them when found out, deserves most Encouragement.

An Hydrostatical PARADOX *explain'd.*

MEETING with Objections in Print, to disprove, by fallacious Reasoning, what I have truely asserted from Experience: I here beg leave to offer this as an Explanation of the Paradox, which an Objector represents as a Falshood. I asserted, " That I had play'd Water (on a calm Day) " upright to the Grass-hopper on the *Royal-Exchange*, which is 55 Yards " high,

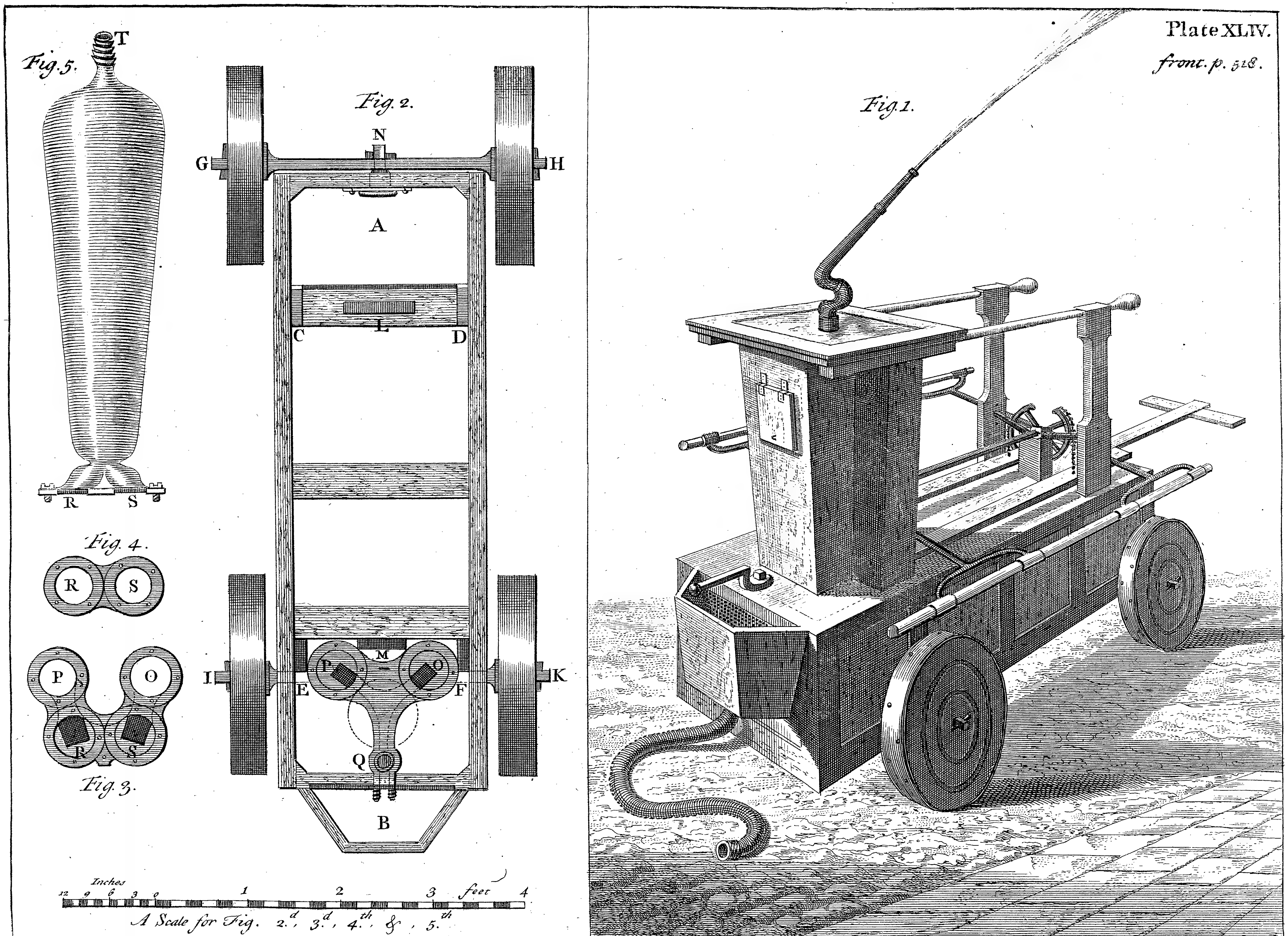


Fig. 1.
Fig. 2.
N
G
H
A
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Fig. 5.
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Fig. 4.
R
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Fig. 3.
P
O
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Inches
12 9 6 3 0
1
2
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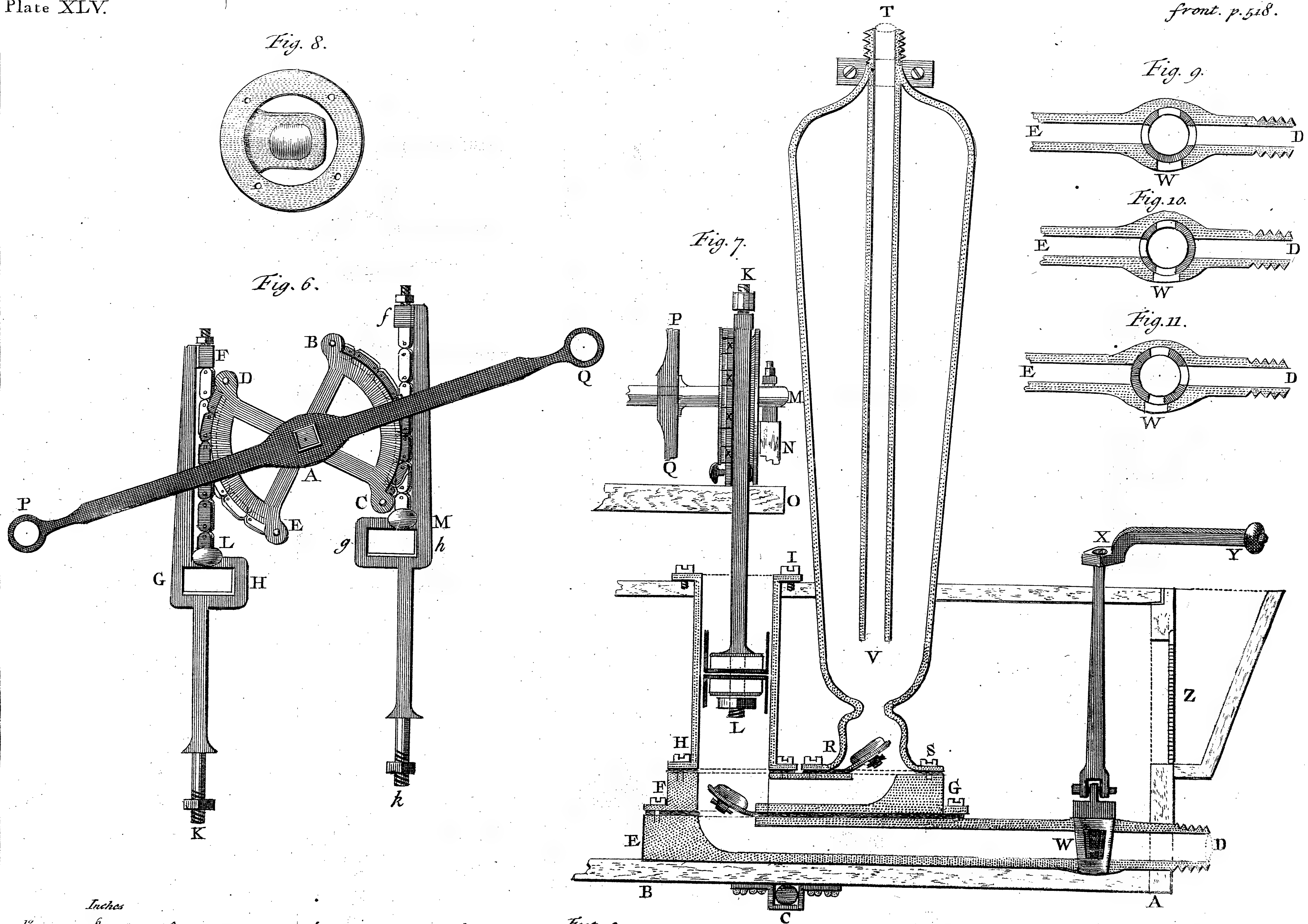
feet
4
A Scale for Fig. 2.d, 3.d, 4.th & 5.th

J. Mynde sc.

Plate XLV.

front. p. 518.



A Scale for Figures 6.th 7.th 8.th 9.th 10.th & 11.th

J. Mynde sc.

" high, with my fifth Size Engine, which plays 170 Gallons a Minute." This was ſeen by many then preſent; yet this Engine cannot throw Water above 50 Yards of horizontal Diſtance, tho' the Spout be elevated to the moſt advantageous Angle. Now a Stone, or Bullet, does certainly go farther in Length, than in Height, when diſcharged by an equal Power: Therefore the Objector ſays, " That by the ſame Laws, Water ſhould ſpout " much farther in Length than Height," (contrary to my Aſſertion of the Matter of Fact.) Yet it is well known, that when Water is thrown to an horizontal Diſtance with great Force, the Stream ſpreads towards the End, and therefore being more reſiſted by the *Air*, falls ſooner: But when a Stream is thrown upright, with this ſame Force, and thro' the ſame Bore, in a calm warm Day, it then makes a ſmall perpendicular Cylinder in the *Air*, (*which thus far aloft is much lighter*) ſo riſes up the *ſame* in a cloſer Pillar to the top; therefore it goes the greater Diſtance in Height.

When a Stream is play'd horizontally, then upright, thro' the ſame Bore, (as above) by an equal Power, not able to throw it above 30 Yards forwards, then the horizontal Diſtance may be greater than the vertical; becauſe, in ſuch a caſe, the Reſiſtance of the *Air* (*which is as the Square of the Velocity*) is conſiderably leſs to the horizontal Stream: As appears by obſerving, that the Water does not then ſpread at the End, as it does when the great Power is apply'd. This is my humble Opinion, which I here offer to the Curious; but, if I am miſtaken in my Solution, yet the Fact is true: The like has been ſufficiently prov'd, by ſeveral Experiments.

RICHARD NEWSHAM.

Annota-

ANNOTATIONS upon the Twelfth Lecture.

1. [Page 423——*The Reason of the two foregoing Rules will be demonstrated in the Notes.*] Those Rules are made out as follows.

Annotat. Lect. XII.

THE Length of a Pendulum swinging a Second of mean Solar Time (intercepted between the Centers of Suspension and Oscillation) has been found at *London* by some late very accurate Experiments to be not less than 39,126 Inches, and not more than 39,130 Inches, at a Mean 39,128 *English* Inches.

Now it is demonstrated, that the Circumference is to its Diameter multiplied by the square Root of 2, as one Second, or 60‴ is to 27‴,009, the Time requir'd to fall *in vacuo* thro' the Length of such a Pendulum. Moreover, the Spaces fallen thro' in different Times being as the Squares of those Times, the Space a Body falls *in vacuo* in a Second of Time, *will be found* 16,0913 Feet, and its square Root 4,0713 Feet.

AND at the End of that Time of one Second, the Body will have acquir'd a Velocity of 32,1826 Feet per Second. Now since those Velocities are as the square Roots of the Spaces fallen thro'; if any Space fallen thro' be $= S$, and the Velocity acquir'd be equal to V Feet per Second, we shall have this Analogy, $\overset{Feet}{4{,}0713} : 2\sqrt[2]{S} :: \overset{Feet}{32{,}1826} : V$, whence $\frac{32{,}1826 \times \sqrt{S}}{4{,}0713} = V$; that is, $8{,}02298 \sqrt{S} = V$, or $64{,}2882 \times S = VV$, which shews the Reason of the first Rule.

AND it is not less evident from the last Equation, that we may conclude that $\frac{VV}{64{,}2882} = S$, which shews the Reason of the second Rule.

2. [Page 436.——*Remarks of mine upon this Engine will be found in the Notes.*] It is not enough to make Pipes of a sufficient Strength to carry Water, according to the greatest Height of the Column, but we must determine the Velocity with which the Water is to run in the Pipes, especially if it be driven from an Engine. I have found by many Observations, that four Feet in a Second is as fast as we ought to drive Water; but if we aim at raising the greatest Quantity possible, our Velocity must be the less; two Feet per Second, or in some Cases but one Foot. But I don't mean that we should thus diminish its Velocity in the same Pipes; for then we should indeed diminish the Quantity: but make our Pipes accordingly larger. But if we aim at making Jets, and causing Water to spout to a great Height or Distance, we must not think to throw up the same Quantity of Water as we could raise to that Height with the same Power properly apply'd. For Example, tho' a Man who can raise a Hogshead of Water in a Minute ten Feet high, will raise half

half a Hogſhead 20 Feet high in the ſame time, and a quarter of a Hogſhead 40 Feet high; yet if uſing the ſame Pump and Piſton he diminiſhes the Diameter of his aſcending Pipe very much, the Friction increaſing will take off from his Quantity. And if cutting off his Pipe near his Engine he puts on an Adjutage, or Spouting-Pipe, in order to make it go the ſame Height without a Pipe; this cannot be done without giving a Friction to *wire-draw* the Water, (as it is call'd:) and ſo much of the Power as is employ'd to give that Friction, ſo much muſt be deducted from the Quantity of Water to be rais'd.

HE that would raiſe a great Quantity of Water by an Engine, muſt not think to have a very good Jet from the ſame Engine; nor muſt he that contrives his Engine for a good Jet, think, with the ſame Engine to raiſe a great Quantity of Water upon occaſion. Indeed with a great deal of Skill in Hydraulicks ſuch a thing may be done, by making proper Changes occaſionally; but it muſt be from the firſt Intention; that is, the Engineer muſt have both theſe Ends in view before he contrives any Part of his Engine. But if an Engine be contriv'd for making a good Jet, it cannot be applied for raiſing the moſt Water to a certain Height in a certain Time: nor can an Engine that raiſes the moſt Water that the Power is capable of, be made to work up a Jet with the beſt Advantage. It would therefore be no unuſeful Problem to propoſe to hydraulical Performers; *The Quantity and Velocity of a Stream of Water, a certain Fall of a certain Quantity of Water, a determinate Number of Men or Horſes being given; to contrive ſuch an Engine, that any of the Powers above-mention'd ſhall produce a Jet of the greateſt Height thro' an Adjutage of a given Diameter; or by a ſudden Alteration in the Engine, raiſe the greateſt Quantity of Water to a given Height.*

THE late Reverend Mr. *Holland*, Miniſter of *Amerſbury* near *Stonehenge* in *Wiltſhire*, had a very great Genius for Mechanicks; but was no Philoſopher, ſo as to be able either to calculate the Force of a Power, or apply it to the beſt Advantage. In that he went by gueſs-work, as moſt of thoſe Perſons do who put up Engines for raiſing Water: for Example, he did not know how to meaſure the Quantity of Water he was to make uſe of, or how to proportion the number of Ladle-Boards or Floats in his Wheels: He knew that a great deal of Friction was to be given to produce a very high Jet with but little Intermiſſion of Variation in the Height; but provided he thought he had Water enough, and that he gave Friction enough, he was ſatisfied. As for the reſt, he was very exact and ſkilful. He ſtrengthen'd his Pipes in the beſt manner: he made all his Work go extremely true; and his Collars and Locks were never thought on before, and ſo accurately perform'd as to have no ſenſible Shake, and the Time of the Forcers working nicely adjuſted. Theſe things being ſo well executed, he ſucceeded wherever he ſet up any of his Engines; except at my Lord *Tinley*'s, where Water, ſince the firſt erecting the Engine, has ſometimes been found inſufficient to play it, tho' when it play'd, every thing expected went right; but that has not been laid to his Charge as a Fault, being by many ſuppos'd not his Buſineſs to conſider; tho' a Philoſopher will ſay it ought to have been conſider'd, and a Wheel muſt have been made accordingly. He erected an Engine for the late Earl of

Annotat. Lect. XII. *Pembroke* many Years ago, which, with a Wheel only of 12 Feet Diameter, performs much better than my Lord *Tinley*'s Engine did when it had not been long set up, and Mr. *Beighton* took a Draught of it in the Year 1720. The present Earl of *Pembroke* having been so good as to favour me very lately with the Proportions of his Engine, I shall thereby be able to make the Comparison of the Wheels and Engines.

MR. *Holland* knew that a Friction must be given to produce Velocity, and make his Jet continuous; but distributed the Friction all over his Pipes, whereas it would have been sufficient to have contracted his Main at the Adjutage, and near it, as I directed to be done when a Jet is supplied by a very high Reservoir, as it may be seen in the Table of the Height of Jets, Page 131, and afterwards Page 137. *Plate* 12. *Fig.* 5. For due Contraction being made at the Adjutage, no more Velocity is requir'd in the Pipe of Conduct than what will supply the Jet of the Height and Adjutage that we want.

THE Faults that my Friend Mr. *Beighton* found with Mr. *Holland*'s Engine are truly *Errors*, as he calls them; but I must animadvert upon them, because what I have to say about them will be useful in other Engines.

FIRST Error. *The Motion is so very slow, that a great deal of Water will slip by the Forcers, unless they are very streight leather'd, and then there are very great Frictions.*

THERE is a way of leathering Pistons, so as to make them support very great Columns of Water without leaking, and increase the Friction very little; which I shall shew in another Note; tho' I believe Mr. *Holland* did not know that Method.

SECOND and third Errors. *The lower Parts of the Cylinders or Pumps are so small, that there's a great Friction in receiving or filling the Pumps. And the Water in the two seven Inch Bores, or two six Inches, is all forced thro' a Pipe of less than three Inch Bore: so the Friction must be prodigious great. For* ——&c. *the Quantity* 85 *must be forced or* Wire-drawn *thro' nine, and in proportion as nine to one.*

THESE indeed happen to be Errors here; but it must not be taken for a general Rule, that *Wire-drawing* the Water, as it is call'd, is always a Fault: for let the Water in a small Pipe go faster than the Water in a large Pipe, either following a Piston of a large Diameter, or going before it; unless this *wire-drawn* Water goes faster than at the rate of four Feet in a Second, the Motion is not too swift, nor the Friction too much. Here the Water is wire-drawn to a Fault, as we shall shew.

THE Water here moves in the seven Inch Barrel according to the Velocity of its Piston, 1,2 Feet per Second; the Water that follows must therefore (as the smallest of the Sucking-Pipes and Valves will force it to go nine times faster) move at the rate of 10,8 Feet per Second, which is twice and an half faster than it ought to do, which makes a considerable Error. But if the Pistons, without any Inconveniency to the Engine, had mov'd so much slower, and been confin'd so to do, that the Water following thro' a small Pipe had fully supplied the Pumps without moving faster in the small Pipe than four Feet in a Second; this would have been so far from an Error,

that

that it would have been a good piece of Oeconomy to have substituted a Pipe and Valves of three Inches in Diameter, instead of making the Pipes and Valves of seven Inches Bore, which would very much increase the Founder's and the Plumber's Bill. I can set this in no better light than by giving an Account of a Trial, wherein the late Mr. *R. Newsham* had like to have been cast in *Westminster Hall*, and made to pay a Penalty for having really serv'd the Proprietors of a Water-work, which he was employ'd to repair. The Case was this: The *Shadwell* Company of Undertakers for raising *Thames*-Water to supply the Neighbourhood, make use of Engines whereby Horses draw round a Wheel, which brings Water into several Pumps, and join into one Main (or Pipe of Conduct running in the Street) the Water of several Pumps, suppose of three, in order to supply the several Streets which those Mains go to, where they are again branch'd into small Pipes to go to private Houses.

MR. *Newsham* observ'd, that in the Part of Horse-work they had given him to mend, there was occasion for three Pumps of seven Inches Bore to keep an Uniformity with the rest of the Horse-work; and that the Water of these three Pumps must be conducted all into a fix'd Main of six Inches Diameter, which could not be alter'd or remov'd. Upon this, (tho' advised to make Valves, and the *Horse* or Communication Piece as big in Water-way as the Barrels) he made them of only four Inches Water-way, because in so doing he sav'd the Company 40 or 50 Pounds in the Expence of Brass, which large Valves, *&c.* would have requir'd: (tho', by the by, we may observe that he would have had his Profit in that, one of his Partners being a Founder.) He consider'd that the Valves, of which there were three, were full as big as the present Occasion requir'd. For example, each Valve being of four Inches Diameter, the Water-way of each may be call'd 16, which multiplied by 3 makes 48, the whole Water-way thro' the three Valves; but the Main to receive this Water being only of six Inch Bore, had only 36 Inches for its Water-way; and therefore could not carry off the whole 48 that the Valves could supply: so that there could be no Hindrance or Check to the Water at the Valves; and therefore if the Water was *Wire-drawn*, it was Wire-drawn thro' the six Inch; for provided the Valves had more Water-way than the Main, no matter what was their Diameter.

Newsham was accus'd of having done the *Shadwell Company* wrong, *in that instead of repairing one of their Engines in an honest and Workman-like Manner, he had set up Valves of so small Water-way, that their Horses work'd the harder in drawing about the Wheel, because the Forcers went so much the harder in their Barrels for the Water being* Wire-drawn; *and that thereby the Tenants could not be serv'd with their full Quantity of Water, as usual, to the great Detriment of the Company*; *and consequently that* Newsham, *instead of being paid for his Work, ought to make Reparation to the Company for the Injury he had done them.*

IT took up some time, and it was with no small Difficulty, that the Plaintiff's Witnesses made the Lawyers understand what was meant by *Wire-drawing* Water; at last it was clear'd up this way.——A Barrel of seven

 Inches

Annotat. Lect. XII. Inches Bore has 49 Inches Water-way; the Valve or Clack is but four Inches Diameter, and its Water-way 16. Now this *Newsham* at every Stroke of every one of his three Pumps has made the Water contain'd in a Barrel of 49 Inches Water-way squeeze thro' an Hole of only 16 Inches Diameter.——— If this could be prov'd, the Jury must *find* for the Plaintiff. It was soon prov'd that Mr. *Newsham*'s Barrels were of seven Inches Bore, and the Valves only of four Inches, and therefore that he had made all the Water of 49 Inches pass thro' 16; and if this was call'd *Wire-drawing* of Water, he had Wire-drawn it very much to the Prejudice of his Employers. When Mr. *Newsham*'s Witnesses (of which I was one) were call'd, it was impossible to make the Lawyers understand, that there could be any kind of Wire-drawing of Water not burthensome to an Engine. They had given their Attention long enough to hydraulical Terms in learning to know what *Wire-drawing of Water* was, to hear with any Patience any thing more concerning the several sorts of Wire-drawing, especially that any sorts of it could be unhurtful. In vain was it shew'd that the Water-way of the Main that carried off all the Water, being but of six Inches Diameter, had but 36 Inches Water-way, and could not carry off all the Water, which his three Valves (whose Water-way taken together was 48 Inches) was continually supplying; and therefore that the Resistance was at this Main, a Pipe not of his laying, and that he could not take away. At last one Gentleman, of more Attention than the rest, with much ado made the Court understand the thing, and prevented the Jury from giving their Verdict for the Plaintiffs against *Newsham*. This shews how Men of the best Sense may be led into great Errors for want of a thorough Attention.

HAVING now shewn that Water is Wire-drawn to Disadvantage in *Holland*'s Engine in the sucking Part, we come to consider the forcing Part; and first, that Part which carries Water to the House without playing the Jet. This Pipe being of the same Bore as the sucking Pipe, the Water does here also run nine times faster than the Pistons move in the Barrels, which here makes it 10,8 Feet in a Second, whereas it ought to have gone but four Feet in a Second; and therefore here also the Water is Wire-drawn to Disadvantage. But if this forcing Pipe had been of five Inches Diameter, the same Quantity of Water, (*viz.* 95 Hogsheads per Hour) would have pass'd thro' with a Velocity of 3,4 Feet per Second, and tho' Wire-drawn in respect of the Water in the Pump-Barrels, would have caus'd no Hindrance to the Motion. Nay, those Barrels that force would have gone easier in their Motions; and therefore, if eas'd in their sucking Part, might have carried $\frac{1}{8}$ more of Water; that is, 107 Hogsheads instead of 95 per Hour, which then would have gone but 3,825 Feet per Second in the forcing or Conduct Pipe. This, instead of Friction, would have given the Wheel a little more Work, which would have reduc'd it to Monf. *Parent*'s *Maximum* to make it go with $\frac{1}{3}$ of the Velocity of the Water.——But this is upon Supposition that the Water was well laid on, and the Float-Boards made in the best manner, and the Pistons rightly leather'd; all which Requisites are wanting.

As

AS for the Jet; there Wire-drawing of Water is necessary; and the Friction which the Pipes suffer'd before, is all transfer'd to the Jet. All that is requir'd besides, is, that the Water has Velocity enough in the Pipes to supply what the Jet consumes, which the Pipes now are more than sufficient to do. Annotat. Lect. XII.

THE way indeed to make a Jet without a Reservoir by this or any other Engine, is to consider what is done in a Jet made by a Fall from a Reservoir, and do the same as nearly as possible by an Engine. Suppose the Jet propos'd is to rise 70 Feet high, and spout thro' an Adjutage of $\frac{3}{4}$ of an Inch Bore. First, see what Height of Reservoir is requir'd to produce a Jet 70 Feet high, which you'll find to be 86 Feet * four Inches: then see what Pipe of Conduct will supply that Jet, if the Adjutage be $\frac{3}{4}$ of an Inch, and you will find the Diameter of such a Pipe of Conduct to be five Inches †: the Velocity of such a Jet is 74,4 Feet per Second ‖, therefore the Water that spouts thro' per Second is 24,8 Yards, which weighs 13,9 Pounds, (because as a Yard of Water of an Inch Diameter weighs one Pound ‡, and this $\frac{3}{4}$ Jet must be diminish'd in proportion of 16 to 9, or the Square of 1 to the Square of $\frac{3}{4}$ the Bore of the Adjutage) and gives 22,3 Tons per Hour. To supply this in a five Inch Pipe, the Water need have no more Velocity than $\frac{55}{100}$ Part of an Inch per Second; but more Velocity in proportion as the Square of the Diameter of the Pipe is less: for Example, in this Pipe of three Inches Diameter, 1,52 Inch per Second will be a sufficient Velocity; but as there must be no Intermission, Mr. *Holland*'s Forcers succeeding one another so exactly, and having their full Force at the Beginning of the Stroke, perform what could not be done with a triple Crank, whose Strokes are weakest at first and at last, unless all the Water was driven first into a very large Air-Vessel; which might be plac'd in a Pond to have a Jet out of its Top, thro' a Pipe coming from its Bottom like that of *Newsham*'s, having hid and cover'd it with Rock-Work. N. B. *One made of cast Iron of about a Yard Diameter, and* 12 *Feet high, might be useful in such a Case.*

* Page 133.
† Page 134.
‖ Page 423.
‡ Page 136.

HERE follows a Comparison of the Right Honourable the Earl of *Pembroke*'s Engine at *Wilton*, put up by Mr. *Holland* many Years ago, and the Right Honourable the Lord *Tinley*'s Engine (here describ'd) put up at *Wanstead* many Years since that at *Wilton*; notwithstanding which, better Jets are produc'd at *Wilton* by an under-shot Wheel of 12 Feet Diameter, than by the under-shot Wheel at *Wanstead* of 30.

THE Diameter of the Wheel at *Wilton* is 12 Feet.

THE Fall of the Water about five Feet.

THE Ladle-Boards which dip 10 Inches in Water are 31 Inches long; therefore their Surface is 2,15 Feet.

THE Weight of the Column of Water pressing on those Ladle-Boards is equal to the Weight of 10,75 cubic Feet of Water *.

* Page 423.

AS the Wheel is but of 12 Foot Diameter, and the Axis 2 Foot, the Radius that acts, or Lever of the second kind, is but of 5 Foot in Length, but the Distance of Power 5 Foot, by which multiplying 10,75 cubic Feet of Water, you will have 53,75 cubick Feet, or 3359 lb. of Water, for the

Annotat. Lect. XII. Pressure of the Power, which carrying the Wheel $7\frac{1}{2}$ times round in a Minute, drives out of the Pump-Barrels a Column of 135 Feet in Length equal to the mean Bore of the Barrels, and play as Jet of $\frac{3}{4}$ of an Inch Adjutage, 70 and sometimes 80 Foot high.

THE Wheel at *Wanstead* has its Ladle-Boards 1,5 Feet in Surface, so that a Column of Water of 7 Foot high weighs against it 10,5 cubic Feet; then acting with a Lever whose Power is distant 14 Foot, must make a Pressure of 73,5 cubic Feet of Water, or 4593 ℔. Yet with all this Advantage of Power, this Wheel drives thro' the Barrels but a Column of 72 Feet in a Minute.

As this Wheel is $2\frac{1}{2}$ times bigger in Diameter than the *Wilton* Wheel, its Circumference ought to have moved twice and an half faster to have exceeded it in that proportion, as to its Ease of Motion; for its Number of Turns must have been equal to have made the same Number of Strokes.

NOW at *Wanstead* the natural Velocity of the Water is 1260 Foot *per* Minute, and the Velocity of the Circumference of the Wheel is 470 Foot *per* Minute; which is as 1 to 2,68.

BUT the Wheel at *Wilton* goes 288 Feet *per* Minute, the Velocity of the Water 894 Foot *per* Minute; so that the Wheel goes with about $\frac{1}{3}$ of the Velocity of the Water: and this brings the *Wilton* Wheel to Mr. *Parent*'s *Maximum*.

THE reason that this could not be done at *Wanstead*, was the bad Application of a sufficient Power. For the Number of the Ladle-Boards of the *Wanstead* Wheel should not have been above 18, and it was above 30; and the *Wilton* Wheel had 11 or 12 Ladle-Boards according to its just Number. See Page 426. *N. B. There is also more Water-way in the Pipes at* Wilton. There is therefore reason to think that when Mr. *Holland* set up the Engine at *Wilton*, he saw an Undershot-Wheel going well somewhere, and imitated it; but he follow'd his own Conjecture at *Wanstead*, without being acquainted with sufficient Principles; thinking in general that a longer Leaver was sufficient to produce a greater Effect, and that contracting his Pipe would give a higher Jet.

NOTWITHSTANDING the Faults that I have found with Mr. *Holland*'s Engine, they had their Merit; for where he had Water enough, he always gave beautiful Jets and with little or no Intermission, which must please the Person for whom the Machine was erected, tho' some Things were not performed according to the strict Rules of Art, which the Owner of the Engine is not supposed to understand. Mr. *Holland*, being modest to a Fault, was often cheated of the Profits as well as the Honour of his Invention; for he was certainly the first who contriv'd to make a Jet without a Reservoir. But I will do his Memory justice, in respect to what came to my knowledge. A certain Person, who wanted to be chosen Representative for the Town of *Shaftsbury*, undertook to supply that Town with Water, to gain his Election by the Merit and Expence of that Performance; and accordingly got Mr. *Holland* to put up one of his Engines, which performed very well; but was himself so careless of his Engineer, as to let him be arrested for the Work of

several

feveral Parts of the Machine: befides, he gave himfelf out as the Author and Contriver of the Engine, calling it his Water-Engine. He made his late Majefty, and all the Gentlemen and Ladies that came with the King from *Hanover*, believe this Performance to be his, and talk'd himfelf into the Place of being *Surveyor of the Board of Works*. A late Right Honourable Perfon, living near Mr. *Holland*, told me this, and bad me make no fecret of it. Afterwards this Gentleman prevailed with his Majefty to let him erect one of thefe Engines for him at his Gardens at *Herenhaufen*, which now performs very well, having for Power the Force of a whole River. But Mr. *Holland* had neither the Credit of this Machine, nor any of the Profit of it; tho' his Majefty paid three times as much as was agreed for. Mr. *B*——— took away Mr. *Holland*'s Smith and Foreman, which is one *John Cleve*, (if not dead, now ftill at *Herenhaufen*,) and by this Man the Engine was put up, tho' he now and then, wanting his Mafter, found confiderable Difficulties. Nay, all the Perfons concerned in the executive Part of this Work were fo ignorant, as to make an Elbow at right Angles in the Pipe of Conduct near the Adjutage, where the Jet was to fpout, fuch as is defcrib'd in the 3d Figure of *Plate* 12. (fee Page 137.) So that when his late Majefty and the whole Court came to fee the firft Trial of this famous and coftly Engine, the Water inftead of fpouting an hundred Foot high, fpouted only ten Foot; and they knew fo little where the Fault lay, that one *Andrew* who had the Management, and appeared as firft in this Undertaking, was ready to run away with all his Men, unlefs by petitioning the Board they could get leave to put up a Refervoir to fupply their Jet.

Annotat. Lect. XII.

By chance as they made their complaint to one *John Helot*, a *French* Watchmaker, and telling him they were all ruin'd; he told them that when he faw the End of their Pipe of Conduct turn'd up to an Angle of 90 Degrees near the Spout or Adjutage, he never expected the Water would rife to the Height they propos'd; but that he believ'd it would anfwer Expectation, if they turn'd up their Pipe with a Curve, fuch as he then drew with his Cane in the Sand. (See *Plate* 12. *Fig.* 4.)

Andrew took the hint, and communicating the Thing to *Cleve*, they alter'd their Pipe accordingly, and in a few days the Jet play'd near 100 Foot high; pretending that they had been cleaning the Pipes that were choak'd up with many Shavings of Wood, carefully concealing their Blunder. But they fail'd in one thing, which was the making a Prefent to *John Helot*, whom, if they did not intend to reward for his Advice, they might have brib'd to Secrecy; and then hundreds would not have known their Ignorance, which *Helot* has acquainted with it.

I SHOULD not have been fo prolix in my Remarks upon this Engine, but that it has fupplied me with Examples to apply a great many of the Rules for feveral Cafes in Hydraulicks, to which I have referr'd, quoting the Pages where the Rules are to be found in the Margin.

Annotat. Lect. XII.

3. [*I shall add a few more Remarks concerning what my Friend has said concerning these Water-Works in the Notes.*]

MR. *Sorocold* put up this Engine at *London*-Bridge, between 30 and 40 Years ago, which remains, and will for many last, as an Instance of the Excellency of its Erector. As for the Contrivance for raising and falling the Water-Wheel, that was the Invention of Mr. *Hadley*, who put up the first of that kind at *Worcester*, and for which a Patent was granted him.

Pag. 439. IT is true that a great deal of Water is lost by the too great frequency of Valves opening and shutting, and therefore that there would be more Water rais'd by fewer Barrels whose Strokes should be proportionably longer; and likewise that a triple Crank distributes the Power better than a quadruple one, which may be only consider'd as a double Crank double loaded.

I HAVE observed a Fault in this Engine about 20 Years ago, and which has not been remedied yet; which is, that they make their forcing Pistons of very stiff Leather, one dishing upwards, and the other downwards, which they drive in with a Mallet; insomuch that I have often seen it require 50 Pounds to move the Piston up and down the Barrel when new leather'd: and after some time, when this thick Leather is thoroughly soak'd, a great deal of Water has slipp'd by; first so as to increase the Friction very much, and to lose a great deal of Water.

FORCERS made with thin Leather tann'd, of about the Thickness of the upper Leather of a Countryman's Shoe, (such as are call'd the second sort of Forcers in Page 161, and represented in the 14th *Plate*, *Fig*. 33, 34, 35, 36, 37, and 38) are sufficient to hold a Column of Water 100 Feet high. Their whole Excellency consists in this, *viz*. that the guiding Brass Cylinder between the Leather fits so well, as just to slip up and down in the Barrel that must be well bored; and if you use a Bucket, the single Leather which looks upwards must rise between the smaller Ring of Brass above it, without coming up too high: as we have suppos'd the two Leathers of the Forcer not to rise or sink below the Rings within them. I have known Mr. *Clarke* (the Turner of whom I spoke concerning the Hydrometer) raise Water to its *Maximum*, with a very bad Engine, where a little weak Horse carried round a single Crank, and raised an Hogshead in a Minute 50 Foot, and held it an Hour during the Trial that I made of measuring the Water, and could have held it 8 Hours.

N. B. *Where Brass Barrels are used, Forcers of thick Leather will soon* chamber; *that is, become wider in the working Part, than at the Mouth or lower; so that a Piston that would go in at the Mouth with difficulty, would go too easy in the* chamber'd *Part. Pistons of soft Leather will not so soon* chamber, *but yet they will in time: therefore the Pistons in their working must rise with their upper Leather half out above the Top of the Barrel, and the lower must go down partly into the hollow made at the Bottom of each Barrel for the rising of the Valves.* This is the Method that Mr. *Newsham* used constantly.

MY

My Friend thinks that the Bores that carry off the Water from the Engines are too ſmall, there being (nearly) always two Pillars of ſeven Inches Diameter forcing into one Pipe of the ſame Diameter, and $7 \times 7 = 49 + 49 = 98$. Annotat. Lect. XII.

But what I have ſaid in the laſt Note will ſhew that this Objection is of no force, unleſs the Velocity of the Piſtons was very great; but here the Velocity of the Water going thro' the Boards above-mention'd, is much leſs than two Feet in a Second. For as each Revolution of a Wheel makes in a Forcer under 2,5 Strokes, and the Stroke is 2,5 Feet: Multiply $2{,}5 \times 2{,}5 = 6{,}25$; and the Wheel at moſt going only ſix times in a Minute, the Velocity of the Forcer will be but $6 \times 6{,}25 = 37{,}50$: ſo that double that Velocity will be but 75 Feet in a Minute, or one Foot and a quarter in a Second.

In this Machine the Cogs are made of Iron, to be the more durable; but there is a farther Improvement by Mr. *Clarke*, which will do very well here, and in any Mill-work. As he has ſent me a Draught and Account of it, I could not refuſe to inſert his Deſcription here.

A LETTER *from Mr.* Clarke *to the Author.*

Sir;

" MANY Attempts having been made for leſſening or taking off the " Friction in all ſorts of Mill-work for grinding Corn, raiſing Water, " *&c.* and nothing having been perform'd to anſwer that End well, I have " contriv'd and invented a new Wallower or Trundle-head, which is fix'd " to Works at the Water-works in *Villars-ſtreet*, *York-buildings*, to an Engine " whoſe Barrels are ſeven Inches Bore, and is wrought by ſeven Horſes. This " Wallower is ſo contriv'd, that as ſoon as the Cogs touch or bear againſt " the Surface of the Rounds or Staves, the Parts of the Surface preſs'd againſt " immediately give way, and in no wiſe rub or grind againſt each other; " and as the Rounds or Staves are made of Iron, they are no way liable to De- " cay, and the Rounds all working in Braſs Sockets, that not only eaſes the " Friction, but preſerves the Wallower from wanting the leaſt repairing many " Years, neither does it wear out the Cogs of the great Wheel, as other " Wallowers do. Here the great Wheel has one hundred and forty-ſeven " Cogs on the Face thereof. As the Mill-wright found great fault with " this way of working when firſt erected, and ſaid the Cogs would wear out " in two Months time, by reaſon of the Wood working againſt Iron; I " therefore, to prove the contrary, would not ſuffer either Cogs or Rounds to " be either greas'd, ſoap'd, or any other Method made uſe of to preſerve " them from wearing each other away, for twelve Months after it was ſet to " work, and it has now work'd conſtantly ſixteen Hours a Day for near two " Years, yet the Cogs are very little worſe than when they were firſt ſet " to work; a Draught of this Wallower I have here ſent you, and am, " Reverend Sir,

Your obliged, humble Servant,

J. Clarke.

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Plate 36. Fig. 2.

Plate 36. *Fig.* 2.

A A a ſquare Iron Bar of an Inch Diameter, and fourteen Inches long, turn'd down to the Size of an Inch, about two Inches at each End *a e*.

B one of the Bars before-mention'd, having Iron caſt thereon of the Diameter of 2 $\frac{1}{8}$ Inches, as from C, C, and in Length ten Inches from E E.

THE Plan of F G I H, a ſquare Braſs Box with its Hole and Pipe at K, for the Gudgeons A *e* or B of the Rounds to turn.

f, *g*, *d*, ſmall Holes to receive Screws, which faſten this Box to the Trundle-head.

F K G, the Upright of the ſame Braſs Box.

Fig. 3. SHEWS the Plan of one of the Trundle-heads mark'd with the ſame Letters.

4. [*I ſhall give a few Obſervations upon this Machine in the Notes.*] When he that comes to take a View of the Engine at *Marly*, ſees it cover a Mile of Ground in Length, and the Breadth greater than that of the whole River *Seine*; he cannot but look upon it as a ſtupendous Machine: and if he is ſkill'd in Mathematicks, Mechanicks, and Hydroſtaticks, he will ſoon perceive that *Rannequin*, the Contriver, was a curious practical Mechanick, but no Mathematician nor Philoſopher; otherwiſe he would have been able to have calculated the Power of the River, and to have known that there was no occaſion for making three Lifts of the Water, which might have been convey'd from the River at once in Iron Pipes. His conveying Motion to a third, and to two thirds of the Height of the Mountain, was admirably well contriv'd, if there had been a neceſſity for it: and there are a great many ingenious Contrivances to take off any one Part of the Work to mend or clean it, whilſt the reſt goes on; and many pretty Inventions to prevent Accidents. The Miſmanagement of Power cannot be better ſhewn, than by comparing the Effect of the Engine at *Marly*, with the Effects of the Water-works at *London-Bridge*. There are fourteen Wheels at *Marly* of thirty-ſix Inches Diameter each, work'd with a Fall of Water of three Feet, which raiſe but five thouſand two hundred and fifty-eight Tons in twenty-four Hours: whereas the *London-Bridge* Works with four Wheels only raiſe eleven thouſand ſeven hundred and twenty-four Tons in the ſame Time, which is almoſt twice and a quarter as much.

I DON'T mean by this that the *London-Bridge* Water-work with its four Wheels performs twice and a quarter more than the fourteen Wheels at *Marly*, ſince the Bridge-Works raiſe their Water but an hundred and twenty *Engliſh* Feet high; whilſt the *Marly* Engine raiſes its Water five hundred *French* Feet, which are equal to five hundred and thirty-three *Engliſh* Feet. But we will conſider theſe different Heights, and find how much Water four Wheels of the *Marly* Engine, and the four Wheels of the *London-Bridge* Engine can raiſe to the ſaid Height of five hundred and thirty-three Feet, according to the preſent rate of the working of each Engine; which will give us a fair Compariſon.

DIVIDING

DIVIDING 5258 (the Tons of Water rais'd by *Marly* Engine in 24 Hours) by 14, will give 375; which multiplied again by 4, will give us $\frac{4}{14}$, or 14000 Tons, the Quantity of Water rais'd in a Day by four of the *Marly* Wheels. Besides this, we are to consider that there is a Fall of Water of three Feet acting upon the *Marly* Wheels: so that we must take away $\frac{1}{3}$, or 466 Tons from the Quantity of Water rais'd by the four *Marly* Wheels, whose Effect we have been examining; because the Fall at *London-Bridge* is but two Feet at a Mean, and then we shall have $1400 - 466 = 934$, the Water rais'd by the four Wheels. Annotat. Lect. XII.

To know what Quantity of Water the *London-Bridge* Work would raise to the same Height as *Marly* Engine, we must make this Analogy.

As 533 Feet, the Height of *Marly* Reservoir:
Is to 120 Feet, the Height of the *London-Bridge* Reservoir::
So are 11724 Tons rais'd 120 Feet by *London-Bridge* Engine:
To the Number of Tons that it would raise in the same Time 533 Feet, or the Height of *Marly* Engine; *viz.* 2839 Ton.

Now as 2839 is three times more than 934, so much is the Effect of the four Wheels at *London-Bridge* greater than that of four of the Wheels at *Marly*.

IT is said that the Machine at *Marly* cost above eighty Millions of *French* Livres, which is above four Millions of Pounds Sterling.

SOME of the largest of our Fire-Engines at present in use in *England*, will raise as much Water to the same Height, and not cost above ten thousand Pounds.

5. [*A Comparison between this Mill, and the Undershot Mill that I have describ'd from Monf.* Belidor, *the Reader will find in the Notes.*] Monf. *Belidor*, by the particular Account which he gives of Under-shot Mills, and their several Parts; and the Calculations concerning the Operations of the Parts singly, and the Whole together, shew'd that he had well examin'd those Mills: but he knew very little of Over-shot Mills, which he speaks very slightly of, saying that the Millers value them very little; but it must be such Millers as live in a flat Country, and are only used to Mills upon Rivers and large Brooks; for in hilly Countries, the Over-shot Mills are of vast Service, and use so little Water, as often to do good Work by the Water of Ponds supplied by Springs. As in this *Nuneaton* Mill, with the Expence of only 1148 Hogsheads, or 287 Tons per Hour, 30 Bushels or 1800 Pounds of Corn, are ground in 12 Hours. The Under-shot Mill describ'd by *Monf. Belidor* does indeed grind about twice and an half more Corn, *viz.* 4500 Pounds in 12 Hours; but it is with the Expence of 24 times more Water. For if the Ladle-Boards of this Under-shot Mill be three Feet long, and go 12 Inches in Water, and the Adjutage or Passage of the Water against them be in the same Proportion with an Height of Water $7\frac{1}{2}$ Feet above the Center of the Adjutage, as in the Over-shot Mill; the Expence of Water will be 6820 Ton per Hour in the Under-shot Mill: whereas the Expence of Water in the Over-shot, thro' an Adjutage $10\frac{1}{2}$ Inches wide, and two Inches deep, is only 287

 Tons

Annotat. Lect. XII. Tons per Hour. To prove which, only consult the Rules given in Page 422, 423, and 424.

I HAVE had occasion to examine many Under-ſhot and Over-ſhot Mills, and generally found that a well-made Over-ſhot Mill ground as much Corn in the ſame time as an Under-ſhot Mill with ten times leſs Water: ſuppoſing the Fall of Water at the Over-ſhot to be 20 Feet, and at the Under-ſhot to be about ſix or ſeven Feet. I generally obſerv'd, that the Wheel of the Over-ſhot Mill was of 15 or 16 Feet Diameter, with an Head of Water of four or five Feet, to drive the Water into the Buckets with ſome *Momentum.*

IT is a difficult thing, and requires ſome Experiments to determine, whether there ſhould be any Impulſe given in an Over-ſhot Mill; or rather a Wheel made of ſuch a large Diameter as to receive the Water without any Percuſſion, by which means it may go with leſs Water; and thoſe who are for this Method alledge, that beſides the Obliquity of the Impulſe when a Fall is made uſe of, there is only the firſt Beginning of the Jet that can do any thing, the ſpouting Water daſhing in the Water that is already in the Bucket, and making a Froth. For my part, I can determine nothing certain in this for want of ſufficient Experiments; but I think that there might be ſome Fall allow'd, that the Momentum might be uſeful at firſt while the Water ſtrikes againſt the Wood of the Bucket, before the Bucket is ſo full that the Water daſhes againſt Water. The determining this, to know what Part of the Height of the Fall muſt be taken for the Diameter of an Over-ſhot Wheel, would be a uſeful *Maximum.* Too great an Impulſe might make the Wheel go ſo faſt; that it might, as it were, withdraw itſelf from the Action of the ſtatical Weight.

THE Velocity that *Monſ. Parent* determines in his *Maximum* for the Under-ſhot Wheel may perhaps be the beſt here; tho' it has not been demonſtrated to be ſo. But here it is ſo, the Velocity of the Wheel is the third of that of the Water; and the Goodneſs of this Mill ſhews it to be right.

THE Objection which Mr. *Beighton* thinks may be made as to the Train is of no Force here; for tho' in Clock-work the Number of the Pinion ſhould equally divide the Wheel, leſt a Leaf of the Pinion ſhould fall foul upon the Edge of a Tooth; it is an Excellency in Mill-work not to have the Number of the Trundle to be an aliquot Part of the Number of the Spur-Wheel, becauſe that way the Rounds are worn out too faſt, when the ſame Cogs too often take the ſame Rounds: and very likely this was done on purpoſe.

6. [P. 474——11——*almoſt every Improvement has been owing to them, as I ſhall ſhew in the Notes; where I ſhall give the Hiſtory of thoſe Improvements.*]

An Account of the Inventors or Improvers of the ſeveral Parts of the Fire-Engine.

About the Year 1710. *Tho. Newcomen*, Ironmonger, and *John Calley*, Glazier, of *Dartmouth* in the *County* of *Southampton*, (Anabaptiſts) made then ſeveral Experiments in private, and having brought it to work with a Piſton, &c. in the latter End of the Year 1711, made Propoſals to draw the Water at *Griff* in *Warwickſhire*; but their Invention meeting not with Reception, in *March* following,

lowing, thro' the Acquaintance of Mr. *Potter* of *Bromsgrove* in *Worcestershire*, they bargain'd to draw Water for Mr. *Back* of *Woolverhampton*, where, after a great many laborious Attempts, they did make the Engine work; but not being either Philosophers to understand the Reasons, or Mathematicians enough, to calculate the Powers, and to proportion the Parts, very luckily by Accident found what they sought for. They were at a loss about the Pumps, but being so near *Birmingham*, and having the Assistance of so many admirable and ingenious Workmen, they soon came to the Method of making the Pump-Valves, Clacks and Buckets; whereas they had but an imperfect Notion of them before. One Thing is very remarkable; as they at first were working, they were surpriz'd to see the Engine go several Strokes, and very quick together, when after a Search they found a Hole in the Piston, which let the cold Water in to condense the Steam in the Inside of the Cylinder, whereas before they had always done it on the Outside. They used before to work with a Buoy in the Cylinder inclos'd in a Pipe, which Buoy rose when the Steam was strong, and open'd the Injection, and made a Stroke *; thereby they were capable of only giving six, eight, or ten Strokes in a Minute, 'till a Boy, *Humphry Potter*, who attended the Engine, added (what he call'd *Scoggan*) a Catch that the Beam Q always open'd: and then it would go 15 or 16 Strokes in a Minute. But this being perplexed with Catches and Strings, Mr. *Henry Beighton*, in an Engine he had built at *Newcastle* on *Tyne* in 1718, took them all away, the Beam itself simply supplying all much better. N. B. *About the Year* 1717, *I communicated to Mr.* H. Beighton *the Use of the Steel-Yard over the Puppet-Clack, or Safety-Valve, which he applied to some Engines.* The way of leathering the Piston was found by Accident about 1713: having then screw'd a large broad Piece of Leather to the Piston, which turn'd up the Sides of the Cylinder two or three Inches; in working it wore through, and cut that Piece from the other, which falling flat on the Piston, wrought with its Edge to the Cylinder, and having been in a long time, was worn very narrow; which being taken out, they had the happy Discovery, whereby they found that a Bridle Rein, or even a soft thick Piece of Rope or Match going round would make the Piston Air and Water-tight.

Annotat. Lect. XII.

BUCKETS and VALVES, 1712.

INJECTION.

SCOGGAN, 1713.

1718.

LEATHERING PISTON, 1713.

MR. *Beighton*'s Account of an Experiment which he made on the Fire-Engine to know what Quantity of Steam a Cubical Inch of Water produces, which I thought very well worth mentioning here.

I FOUND by several Experiments by a divided Steel-yard on the Puppet or Safety-Valve on the Top of the Boilers at *Griff* and *Wasington*, that when the Elasticity of Steam was just one Pound Averdupoids on a square Inch, it was sufficient to work the Engine, and that about five Pints in a Minute would feed the Boiler as fast as it consum'd in boiling and Steam for the Cylinder 16 Strokes in a Minute. *Griff* Cylinder held 113 Gallons of Steam every Stroke × by 16 Strokes in a Minute = 1808 Ale Gallons; so five Pints of Water produc'd 1808 Gallons of Steam, 38,2 Cubic Inches in one Pint. Then 38,2 Inches : 1808 Gallons : : 1 Inch : 47 Gallons three Tenths: hence it appears one Cubic

* *The Manner of this working with a Buoy would be tedious, and require a particular Figure to explain; but since it is now out of Use, it is needless to do it.*

Annotat. Lect. XII. Cubic Inch of Water by boiling 'till its Elasticity is capable of overcoming about $\frac{1}{13}$ of the Atmosphere, will make 13 thousand 338 Cubic Inches of Steam.

By Experiment I have found that out of the Eduction-Valve of a 32 Inch Cylinder there comes out one Gallon each Stroke; it is surprising how that Steam, which is made of about three Cubic Inches of Water should heat one Gallon of cold Water, so as to have it come out scalding hot, which it does, and the Cylinder in all its upper Part is but warm when the Piston is down.

N. B. *I take this Opportunity to beg of the Reader to rectify a Mistake, made in* Page 473. *because the Sheet is printed off. It is this, in the 32d Line of that Page, read,* Air will precipitate in Steam, as Quicksilver would in Water.

7. [Page 484——*I have done with the Fire-Engine——except some few Things which I shall mention in the Notes.*] I cannot better end my Observations on the Fire-Engine, than by giving the Reader Mr. *Beighton*'s Table of the Power of the Fire-Engine, which he publish'd in the Year 1717; because it agrees with all the Experiments made ever since.

A Calculation of the POWER of the FIRE-ENGINE: shewing the Diameter of the Cylinder, (or Steam-Barrel;) and Bore of the Pump, that is capable of raising any Quantity of Water, from 48 to 440 Hogsheads an Hour; at any Depth from 15 to 100 Yards.

Diameter of Bore.	will hold in a Yard.	will draw by a 6 Feet Stroke.	weighs in one Yard.	at 16 Strokes a Minute.	63 Gallons to a Hogshead.	In one Hour.	Diameter of the Cylinder in Inches. The Depth to be drawn in Yards.												
Inches.	Gallons.	Gallons.	℔ Aver.	Gallons.	Hog. Gal.	Hog. Gal.	15	20	25	30	35	40	45	50	60	70	80	90	100
12	14,4	28,8	146	462.	7.21	440.	18½	21¾	24	26½	28½	30½	32½	34¼	37¼	40			
11	12.13	24	123,5	338.	6.20	369.33	17	19¾	22	34¾	26¼	28	29¾	31¼	34¼	37	39½		
10	10,02	20,04	102	320	5.5	304.48	15½	18	20	22	23¾	25¼	27	28¾	31¼	33¾	36	38¼	40
9	8,12	16,2	82,7	259,8	4.7	247.7	14	16¼	18	20	21½	23	24¼	25	28	30½	33	35	36½
8½	7,26	14,5	73,9	232,3	3.43	221.15	13½	15¼	17¼	19	20¼	21¾	23	24	26¼	28½	31	32½	35¼
8	6,41	12,8	65,3	205.2	3.16	195.22	12½	14½	16½	18½	19	20½	21½	23	25	27	29	30½	32½
7¾	6,01	12,2	61,2	192,3	3.2	182.13	12	14	15½	17½	18¾	19¾	21	22	24¼	26	28	29½	31½
7½	5,66	11,3	57,6	181,1	2.55	172.30	11	13¾	15	16½	18	19	20	21¼	23¼	25	27	28½	30¼
7	4,91	9,8	50,0	157,1	2.31	149.40	10¾	13	14	15½	16¾	18¾	19	20½	22	24	25½	27	28½
6½	4,23	8,4	43.0	135,3	2.9	128,54	10	12	13	14	15½	16¼	18	19	20	22	23	24½	26¼
6	3,61	7,2	36,7	115.5	1.52	110.1	9½	11	12	13	14	15½	16	17	19	20½	22	23	24½
5½	3 13	6.2	31,8	99,2	1.36	94.30		10	11	12	13	14	15	15¾	17	19	20	21	22¼
5	2.51	5.0	25,5	80,3	1.7	66.61			10	11	11¾	13	13¾	14	15½	16¾	18½	19¼	20¼
4½	2,02	2,4	20,5	64,6	1.1	60.60				10	11	11¾	12	13½	14	15	16	17	18¼
4	1,6	3,2	16,2	51,2	0.51	48.51					9	10	11	11½	12	13½	14	15	16

The Table is form'd on this Foundation, *viz.* The Ale Gallon (containing 282 Cubic Inches) fill'd with pure running Water weighs 10 ℔. 3 ʒ. Averdupoids; and a superficial Inch, on a Vacuum, takes in about 14 ℔. 13 ʒ. of the Atmosphere, when the Mercury stands at a Medium in the Barometer.

But allowing for several Frictions, and to give a considerable Velocity to the Engine, Experience has taught us to allow but little more than 8 ℔. to an Inch in the Cylinder's Base, that it may make about 16 Strokes in a Minute, at about six Feet to each Stroke,

This Calculation is but the ordinary Power in Practice, for with large Boilers it will go currently 20 or 25 Strokes per Minute, and each of them seven or eight Feet, and then a Pump of nine Inches Bore will discharge more than 320 Hogsheads per Hour, and for other Sizes proportionably.

An Example of the Use of the Table.

Suppose it were requir'd to draw 150 Hogsheads per Hour at 90 Yards deep; in the seventh Column I find the nearest Number 149 Hogsheads, and against it in the first Column I find a seven Inch Bore; then under 90, the Depth on the right Hand in the same Line, I have 27 Inches, the Diameter of the Cylinder fit for that Purpose——and so for any other.

Hen. Beighton, 1717.

Annotat. Lect. XII. THE Reader may observe, that Mr. *Beighton* in his Calculations makes use of the Ale Gallon, and I make use of the Wine Gallon; but that will make no Difference in the main, because the Hogshead and Ton is the same: and need only observe, that the Ale Gallon contains 282 Cubic Inches, and the Wine Gallon 231; the Ale Pint 38,2 Inches, and the Wine Pint 28,87 Inches.

SOME People make use of cast Iron Cylinders for their Fire-Engines; but I would advise nobody to have them; because tho' there are Workmen that can bore them very smooth, yet none of them can be cast less than an Inch thick, and therefore they can neither be heated nor cool'd so soon as others, which will make a Stroke or two in a Minute difference, whereby an eighth or a tenth less Water will be rais'd. A Brass Cylinder of the largest Size has been cast under $\frac{1}{3}$ of an Inch in Thickness; and at long run the Advantage of heating and cooling quick will recompense the Difference in the first Expence; especially when we consider the intrinsick Value of the Brass.

Page 504, at the End of Section 21. This should be inserted.

IF three or more Men working together are to raise Water but a small Height, as for Example, to empty a Pond, or throw the Water from one Pond to another; they will sooner do it with *Scoops*, than with any Engine or Pump whatsoever; because they have no Friction to overcome.

If we would know from hydraulick Facts, the *Maximum* for an Horse, or the most Water that an Horse can raise to a certain Height in a certain Time, we must examine those plain and simple Instruments used at the Coal-pits, call'd Barrel-Gins, where an Horse going round in a sufficiently large Walk draws round an *Axis in Peritrochio*, whose Axis (or Barrel) being large, has a Rope coil'd upon it to bring up alternately two Vessels of Water from the Bottom of the Mine, to be emptied when they come to the Top. By the Use of this Engine an Horse of middling Force will easily bring up Water at the rate of one Hogshead 50 Feet in a Minute, which is just five times more than a Man can do, as we have said before. There is no Pump, that we know, whereby the same Horse can raise up so much Water to the same Height in the same Time. All the Care must be to have the Vessels that are brought to be emptied quick.

8. [Page 505. *Mr.* Newsham'*s Engine ought not to do it, as I shall shew in the Notes.*] The Excellency of Mr. *Newsham*'s Engine is to have its Jet move with great Velocity, that it may have sufficient Strength to break Windows, and pass thro' into the Fire at the farther End of an House in Flames. This Velocity is produc'd by a Friction which is got by Wire-drawing the Water thro' the conick spouting Pipe that delivers it; whilst the Valves and Leathern Pipes have sufficient Water-way to supply the Jet in its greatest Velocity: but if you screw off the Spout, and deliver your Water in a Cistern, the Retardation from the Friction of the Valves and Pipes will be such, that the Quantity will not come up to the *Maximum* of an Hogshead rais'd in one Minute ten Feet high by one Man.

THE

THE Reader may perhaps wonder that in this Account of such Variety of Engines, I have given no Account of Wind-mills; but I would not do it, because the principal Thing is wanting in them; that is, a Method to make them grind Corn uniformly, when the Wind suddenly varies: for sometimes from scarce bruising the Corn, the Motion is so increas'd, and the Stones go so fast, that the Flower is quite hot and spoil'd. Diminishing the Surface of the Sails is practised, but that can't always be done quick enough for the sudden Increase of the Wind. There might be some Contrivance to give the Mill more Work to do, which it should take of itself, as the Wind rose suddenly, and leave as the Wind grew slack. I don't hear that any body yet has made use of any such Contrivance. I am confident it may be done, and I have design'd it above these twenty Years; but have been hinder'd by other Affairs. But I hope to do it some time or other, if I live. In the mean time, if People are content to make no Advantage of the sudden Increase of the Wind's Velocity; and only desire to be kept from Mischief, they may make use of a large Fly to beat the Air, led by a small Pinion, such as is describ'd in Mr. *Vauloue*'s Pile-driving Engine, Page 417, and 418. But not to be wholly silent on this Subject, I give the following Observations from *Monf. Belidor*, Vol. II. Book 3. Page 33, 38, 40, 41.

Annotat. Lect. XII.

3. WIND was never used for Mills till the Year 1280, or near 1300.

8. THE best Angle with the Axis for the Sails of a Wind-mill is 55 Degrees.

THE Force then is equal to $\frac{5}{13}$ of the Force of the Wind.

40. They make that Angle of 72 Degrees near *Paris*, and thereby lose $\frac{2}{7}$; or have their Effect only as 5 to 7.

41. To have the greatest Effect, or most Work done, the Velocity of the Sails at their Center of Gravity must be equal to $\frac{1}{3}$ of the Velocity of the Wind.

The End of the NOTES.

AN

APPENDIX,

BEING

A SUPPLEMENT to ſome Things wanting in the Firſt Volume.

At Page 100. *Vol.* I. *between the Numbers* 39, *and* 40, *inſert this.*

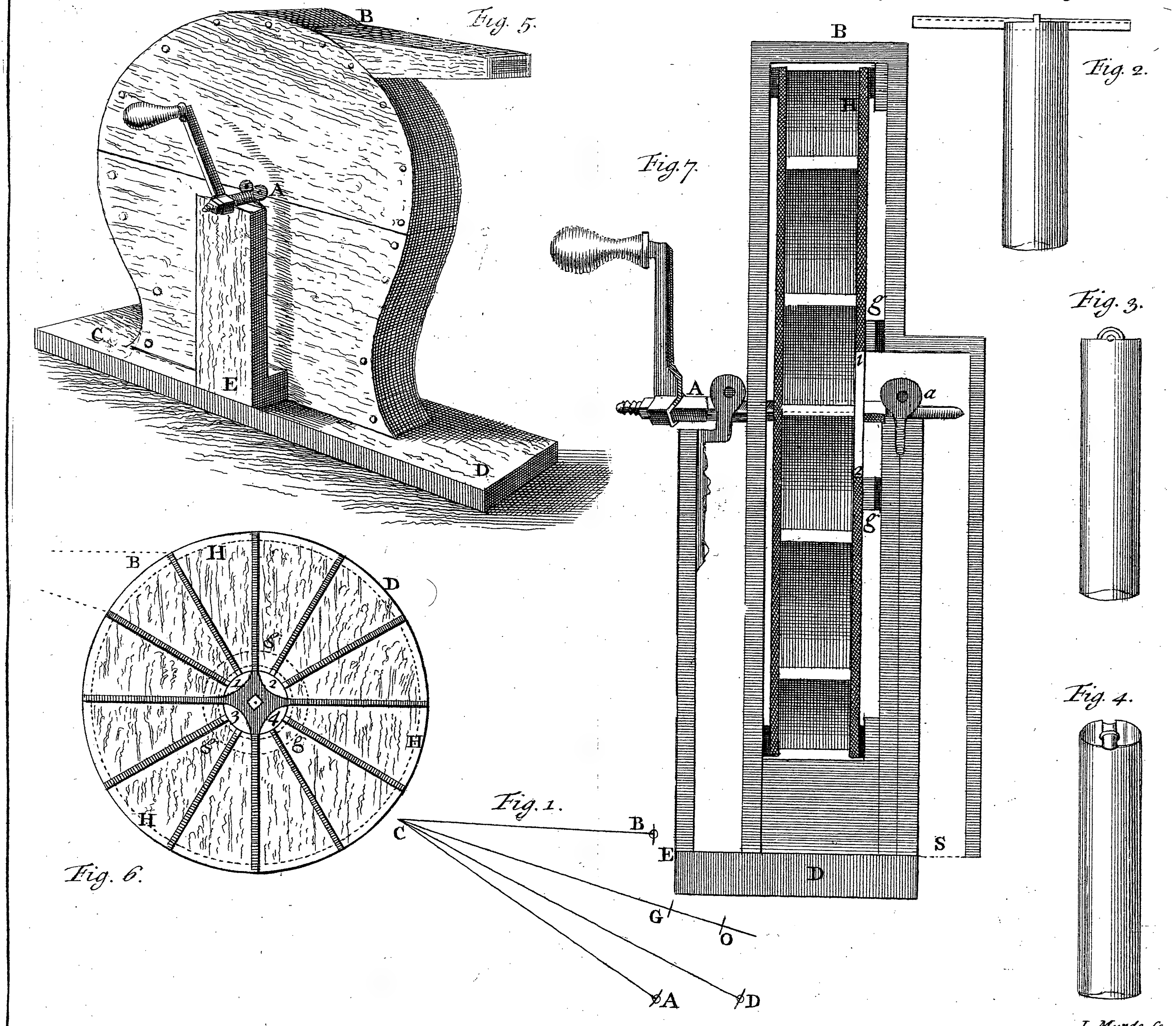
1. WHEN the Ratio of the Power to the Weight (when a Power raiſes a Weight by a Tackle) is conſider'd, it is expreſs'd in theſe Words, *As one is to the Number of the Ropes, or of the Parts of the Rope applied to the lower Pulleys; ſo is the Power to the Weight.* Now, a *moveable Pulley*, tho' it ſhould move downwards, is the ſame as a lower Pulley; as is exemplified in the two Tackles repreſented in *Fig.* 9. and *Fig.* 10. of *Plate* 38. Theſe are only uſed in Merchant-men, and ſeem to be of *Spaniſh* Invention, call'd *Spaniſh Burtons*; in the firſt of which the Power is to the Weight as 5 to 1, and in the other as 4 to 1. In the firſt, 4 Parts of Rope are apply'd to the Pulley H, that riſes with the Weight: and two Parts of the Rope ſeem to be apply'd to the Pulley G that comes down with the Weight, which would be ſix; but one of them being actually the running Rope or Fall, it ſelf muſt be taken out of the Account. So in Tackle of *Fig.* 10. the Power is to the Weight as one to four, three Ropes being applied to the lower Pulley *f*, and one more Part of Rope to the left-ſide of the deſcending Pulley *g*. That the Proportion of the Power and Weight are exactly thus, may be found by applying the reciprocal Proportion of the Velocities of unequal Quantities of Matter that balance one another.

MOUNT the Tackles, and draw down the running Rope five Foot, and you'll find that the Weight riſes juſt one Foot. So in the other the Power coming down four Foot, makes the Weight riſe one.

2.

Plate XLVI.

front.^e the last page.



2. *Page* 190. SINCE the Publication of my first Volume, and before, the Professor of *Leyden*, *Petrus van Muschenbroek*, tried so many Experiments concerning Friction, that I would recommend to my Reader what he has written upon that Subject in his, often quoted, *Essays de Physique*, Vol. I. from Page 176, to Page 188.

3. *At Page* 203. *Vol.* I. *comes in what follows from Mr.* Beighton.

To Dr. DESAGULIERS.

" *Dear Friend*,

" THE Perusal of your Treatise gave me great satisfaction, not ex-
" pecting to meet with so many Things new, after Numbers have
" wrote on those Subjects of late; the Observations I have here made, on
" that Part you collected, I drew out for the Royal Society: A Liberty I
" assumed, as well knowing you to be so great a Lover of Truth, that
" you are wont to be pleased with any Corrections on what you have
" publish'd. If any thing is worth notice, you may please to specify it
" in your Second Volume: For these purposes I have first submitted 'em
" to your Perusal. I am,

" *Reverend SIR*,

" *Your very humble Servant*,

Griff, 28 *Feb*. 1737-8.

HENRY BEIGHTON.

UPON reading Dr. *Desaguliers*'s Course of Philosophy, Quarto, 1734. in his 4th Lecture of the Friction of mechanical Engines, I have considered what he relates from Monf. *de Camus*, on the Wheels of Carriages in Page 203.

" THAT the Axle-Trees must be streight in all respects; for that when
" the Wheels stand narrower at the Ground, and before, than at the
" Top and Hind-part (which is the common and daily Practice of all
" Mankind) they must move more hard."

NOW altho' the Reasoning may be mathematically true, yet there may be some Circumstances, those Gentlemen have not so duly considered, as those whose business it has been either to make or use such Machines; for there may be some considerable Inconveniences in practice, in keeping strictly to those Rules. And the Strength, Conveniency, Usefulness, and Ease, ought to be well weigh'd and consider'd.

1. If Wheels were to move forward in ſtreight Lines, I muſt own the Objections to their Rules might be in ſome meaſure leſſen'd; but as Roads are ſeldom ſtreight Lines, (in which Wheels in motion on a horizontal Plane would always go, if no Obſtacle put them out of it) when your Carriage is to turn to the right-hand, the left-hand would preſs towards the End of the Axle-Tree, and bear hard on the Pin there, and the right Wheel will be thruſt up towards the Shoulder: for then the Axle being put in a diagonal Poſition, between the parallel ſtreight Lines of Wheels before-deſcribed; thoſe Wheels muſt be forced to a greater Diſtance from each other, as the Diagonal is longer than the Perpendicular. And as in ſuch turning to the right, the right-hand Wheel may be conſidered as a Center (if the Turn be ſhort,) the left Wheel is deſcribing a Circumference, and in ſuch direction is endeavouring to fly off or move in the Tangent. But if the Wheels be (as the common practice is) a little narrower before than behind, it will have its natural Direction and Inclination to deſcribe Part of ſuch Circumference.

2. But, a more material Objection to the Rule, is, That as the Boxes in the inward Part of the Naves of large Carriages (and Coaches in proportion) are $5\frac{1}{4}$ Inch Diameter, and the fore Box but $3\frac{3}{4}$, and the Arms on which they move the Fruſtum of a Cone, the Wheels even on level Ground would always be endeavouring to diverge, and at every turn be forcibly running into the Tangent.

3. If the Axle-Trees were in ſuch ſtreight Direction as *Fig.* 1. the Wheels preſs'd by the under Part of the Axle would be continually flying off, and preſſing hard againſt the Pins at *b*, with as great Friction as preſſing on inclin'd Planes, for the ſame reaſon as the double Cone ſeems to run up hill.

4. It muſt be conſidered, that all the Rutts or Tracks of Waggons or Carriages, are cut or ſunk by them nearly perpendicular; and if the Axle-Trees were ſtreight, the Wheels muſt move at right Angles to the Axis.

All Wheels are ſtrongeſt when made concave or diſhing, *viz.* when the Parts of the Spokes at *c* near the Nave in one Wheel, are nearer to thoſe in the other, than the Felloes: Thoſe Spokes muſt be continually rubbing as they go deeper into the Ground, and cutting the Rutts in an oblique Form, as at *Fig.* 3. But in the Poſition of *Fig.* 4. they would enter and come out, without the 4 following Inconveniences which attend the former, *viz.*

I. That it wears the Spokes, and the Stones in the Edges of the Rutts are forced in between them, into a narrower Space, and often break them.

II. The

II. The ſoft or ſtiff Dirt or Clay is thruſt in, and preſs'd as Wedges into a narrower Part, ſo hangs on them ſo as to form them like a Mill-ſtone, to the great Detriment of the Horſes drawing ſuch additional Weights beſides Friction.

III. When the Wheels are forced in and fly outward to the greateſt Extent on the Axis, it would require a double Force to draw the Machine forward.

IV. And in the laſt State, when it is impoſſible the Wheels ſhould be ſeparated any wider, the Carriage can neither turn to the right or left.

5. Considering the Obſtacles Wheels are continually meeting with, they muſt have ſome play, and the Axle-Tree muſt ſlide in and out of the Wheels, ſee *Fig.* 12. elſe they are in conſtant danger of breaking. And as this eaſy ſliding cannot be had, but by the under and fore-part of the Fruſtums being both in continued ſtreight Lines; for a Wedge or double Cone cannot ſlip end-ways without great Force, when two Plains will eaſily; therefore the Axle-Trees ought not to be ſtreight, as Mr. *de Camus* has aſſerted.

The greateſt Characteriſtic of a Carriage's going well and eaſy, is the Axle-Tree's ſlipping continually to and fro in the Naves: For a Man's Ears only will tell him when a Waggon or Coach goes well and eaſy, by hearing it thump againſt the Shoulders and Pins alternately. When it does ſo, the Draught is above one fifth leſs.

☞ The Axle-Trees and Wheels are impreſs'd by two Forces, one the Weight of its Load near perpendicular, the other the Traction or Drawing nearly horizontal; therefore the greateſt Force impreſs'd, is in the Diagonal between the two, but neareſt to that whoſe Force is greateſt. And in that very Part or Surface of the Axle-Trees Arms, the two Fruſtums of Cones ought to be in a continued ſtreight Line.

N. B. If M. *de Camus* could mean the Axle-Trees and Wheels of Coaches, when the Axes are Iron Cylinders, yet even then moſt of the Reaſons I have urged above lie very ſtrong againſt his Rule, and alſo prove it falſe in that reſpect.

4. *And afterwards from the ſame at Page* 211.

Of the Drawing of Horſes, and Line of Traction.

Prop. XXX. Pag. 211. In ſpeaking of Drawing————————

" That the Line of Traction ſhould be on a level with the Breaſt of
" the Horſe, becauſe the Horſes that draw upwards tire ſooner, and grow
" ſtiff in the Hams."

I CONCEIVE this to be a Miſtake; for both Experience and Reaſon too will teach, and demonſtrate the contrary. For,

1. HORSES have little or no power to draw, but what they have from their Weight or Gravity; otherwiſe they could take no hold of the Ground, and then they muſt ſlip, and draw nothing.

2. COMMON Experience teaches us, that if a Horſe is to convey a certain Weight, he ought (that he may draw the better) to have a proportional Weight on his Back or Shoulders. A Horſe put into a two-wheel'd Cart, in which there is a Ton Weight; when it is in an *Æquilibrium*, will not be able to draw it, but when there's 50 or 60 ℔. bearing on his Back, he will draw it with Eaſe. If it be 2 or 3 Ton, if he bears 100 or 200 ℔. on his Back, he will be able to draw the Load, becauſe the Wheels of a Cart are very high. The Horſes Back ſhould be loaded proportionably.

3. THAT Author does not ſeem to know, That when a Horſe draws hard he bends forward, and brings his Breaſt nearer the Ground; and then if the Wheels are high, he is pulling the Carriage againſt the Ground.

4. A HORSE tackled in a Waggon will draw 2 or 3 Ton, becauſe the Point or Line of Traction is below his Breaſt, by reaſon of the Wheels being low.

5. IT is very common to ſee when one Horſe is drawing a heavy Load, his Fore-Feet will riſe from the Ground, and he will nearly ſtand on end; 'tis then uſual to add a Weight on his Back to keep his fore Part down, by a Perſon mounting on him, which will enable him to draw that Load, without which he before could not move.

6. THE Caſe is nearly the ſame, in applying the Strength of a Man in wheeling a Load in a Wheel-barrow; when moſt of the Load lies on the Wheel, he will ſlip, and not be able to get it forward; but then bringing the Weight nearer his Arms, he will be able to drive it forward. In drawing a heavy Garden-Roll, if the Axis of Motion was even with that Part of his Body where his Arms are extended, he could not be able to draw it along; but when the Point of Traction is low, he may.

IN a loaded Cart, which hangs nearly *in æquilibrio*, if two Men would take it by the Shafts or Draughts, they would not be able to move it; but one of them in the Draughts, and the other behind the Cart, puſhing the Breech upward as well as forward, he lays a Load on the firſt Man's Back, and ſo preſſing both the Feet againſt the Ground, they will eaſily do it.

THE common Method with a Lever, either to ſlide or roll a Piece of Wood or Stone, is firſt to lift, and then puſh forward.

IN

In a long Team, where only the hind Horſe bears on his Back; if you take off half the Number, and fix them to a lower Point of Traction, they will be enabled to move a much ſuperior Force.

5. *Then Page* 212. *from the ſame.*

The Poſition of Drawing demonſtrated.

The greateſt Streſs or main Buſineſs of Drawing is to overcome Obſtacles, for on level Plains the Drawing is but little, and there the Horſe's Back need be preſs'd but with a ſmall Weight.

Most or all of theſe Obſtacles may be conſider'd as inclin'd Planes.

To draw the Wheel AB, over the Obſtacle D, *De Camus*, by what he ſays, would have the Horſe draw in the Line HC. Plate 38. Fig. 15.

I Say, as the Obſtacle D, and the Tangent of the Earth or Line of the Floor is B, the Line to be moved in is BD, and an inclin'd Plane; then the eaſieſt Poſition of Drawing to get the Wheel over D is to draw in the Poſition of that inclined Plane BT, or more properly parallel thereto in the Line C*b*.

All the Radii of a Wheel being equal, the pulling at the Center, is the ſame as a Balance *in æquilibrio, viz.* there's the ſame Force at A as at B. But in the Caſe of Drawing in the horizontal Line HC, where there's an Obſtacle at D, all the Force the Horſe has to draw is by the ſhort End of Brachium = *e* D, againſt the Force or Weight of the long End of the Brachium *f* D = C, which muſt be very diſadvantageous: therefore the Line of Traction ſhould be *b* C, and quite contradictory to what that Gentleman has ſo often in his Book aſſerted; in which caſe the Force is applied to a Leaver D*a* much longer than D*e*.

P. 212.——Says Horſes can carry but 200 ℔.

In *Warwickſhire*, from the Coal-Works at *Griff* near *Coventry*, and other Places, it has been uſual for an ordinary Horſe to carry 650 ℔. and ſome have carried 700 ℔. 2*q*. for 7 or 8 Miles without the Horſe ever reſting.

Mr. *Foley*'s Horſe at *Stourbridge* carried 11 hundred Weight of Iron for 8 Miles.

6. *Page* 421. *after the* 10*th Annotation to Lecture* 5*th.*

The Problem concerning the Determination of the Center of Oſcillation has always been look'd upon as one of the fineſt of modern Analyſes. Meſſieurs *Des Cartes*, *Robertval*, and many others, have conſider'd it, and

determin'd

determin'd it; but that only in some Cases. Mr. *Huygens* was but very young when this Problem was propos'd to him by Father *Mersennus*; as he has mention'd in his excellent Treatise, intitled, *de Horologio Oscillatorio*; and he is the first who has given a general Rule for finding that Center. Since that Time almost all the Mathematicians have given other Investigations, and other Demonstrations of *Huygens*'s Rule.

THAT which I shall give here is easy, and to be understood by those who are not skill'd in the Doctrine of Fluxions and Fluents.

THE *Center of Oscillation* of a Body, is that Point wherein the whole Force of a Body that swings is collected in the same manner, that the whole Weight of that Body, when it is at rest, is collected in its Center of Gravity. In order to determine this Point, and give yet a clearer Idea of it, let us suppose several equal Corpuscles, A, B, D, *&c.* join'd together so that they may move only all together, such as are the Atoms or Particles of which a solid Body is compos'd, which swings round an Axis of Oscillation, which is horizontal and perpendicular to this Paper, when the Paper is in a vertical Situation; and let the Force which causes this Body to swing, be either the natural Force of Gravity, or any other Force impress'd. "Now it is requir'd to find a Point, either within, or "without this Body, (or this Assemblage of Particles) in which if all "the Matter was concenter'd, the Vibrations of that Point would be "perform'd exactly in the same time, as those of the Body swinging are "actually perform'd."——Or to express myself yet another way——"It "is requir'd to find the Distance of the Axis of Oscillation; at which "Distance one Corpuscle being plac'd, would perform its Vibrations by "the Velocity that would be given it by Gravity, or any other Force "impress'd, in the same time that those of the Body that swing perform "theirs."

WE must observe at first, that tho' the Points or Corpuscles A, B, D, *&c.* are here in the same Plane, they may be conceiv'd in Planes different from one another: it is sufficient to conceive that the Lines C A, C B, C D, *&c.* represent their Distances from the Axis of Oscillation; tho' those Distances are measur'd from different Points of the Axis, whose Section only is represented by C.

LET G be the common Center of Gravity of the Body, or of the Assemblage of the Corpuscles or Physical Points A, B, D, *&c.* It is certain in the first Place, that the Center of Oscillation must be in C G produc'd one way or the other, if there is occasion; without which, when the Body is come to rest by the Resistance of the Fluid in which it oscillates, and the Friction that there may be about the Center of Suspension, it would not stop at the lowest Point of the Arc that it describes:

it

it is alſo evident, that that Center of Oſcillation muſt be on the ſame Side of the Center of Suſpenſion as the Center of Gravity, ſince without that it cannot remain at reſt, and freely ſuſpended; which happens when the Line C G paſſes thro' that Center of Oſcillation, and thro' the Center of the Earth, (or rather thro' the Center to which all heavy Bodies tend.) Let us ſuppoſe this Center of Oſcillation requir'd to be at ⊙, yet without determining whether the Point O be within or without the Body; it is evident, that ſince the Corpuſcles are join'd together, whether by their ſwinging they deſcribe great or ſmall Arcs, their Velocities will always be proportionable to their Diſtances from the Axis of the Vibration; and conſequently thoſe Diſtances will expreſs their Velocities in all poſſible Caſes. Thus the *Momentum* or Quantity of Motion of the Corpuſcle A will be as $CA \times A$; and for the ſame Reaſon, that of B, will be $CB \times B$; and that of D, will be $CD \times D$, and ſo of the reſt, if you ſuppoſe a greater number of Points or of Corpuſcles.

Now as all the Momenta act at different Diſtances, to know the Sum of their Forces, you muſt reduce them, or as it were transfer them one after another into a Point, which ſhall be the Point ⊙, which you ſeek, (by its Definition.) Thus ſince the Momentum of the Corpuſcle A acts upon the End of an Arm of a Leaver, ſuch as C A, that Momentum carried to ⊙, that is, the Momentum which would be felt at O, by means of that of A acting at A, muſt be the ſame as a Momentum that would be capable of making Æquilibrium with the Momentum of A. And it is plain by the Principles of Mechanicks, that that Momentum muſt be to that of A, in a reciprocal Ratio of their Leavers, or their Diſtances from the Axis; and conſequently it will be found equal to the fourth Term of this Analogy $CO : CA :: CA \times A : \frac{\overline{CA}^2 \times A}{CO}$. For the ſame Reaſon the Momenta of the Corpuſcles B and D, *&c.* being carried to ⊙ will be $\frac{\overline{CB}^2 \times B}{CO}$, and $\frac{\overline{CD}^2 \times D}{CO}$, *&c.* And thus their Sum, or the Momenta of all their Particles A, B, D, *&c.* which is felt at, or is ſuppos'd to be carried to ⊙, will be, $\frac{\overline{CA}^2 \times A + \overline{CB}^2 \times B + \overline{CD}^2 \times D}{CO}$, *&c.*

Now let us ſeek what is the Quantity of Matter, or the Weight which being placed at ⊙ (and conſequently when all the Body is in motion, a Velocity proportionable to C O) ſhall have as much Momentum, or Quantity of Motion, as that which is felt at O by the Action of the Momenta of the Particles A, B, D, *&c.* and whoſe Expreſſion we have juſt found. It is certain, that if G be the common Center of Gravity of the Corpuſcles, their whole Quantity of Matter, or their Weight

being ſuppos'd concenter'd at G, and having a Velocity as C G, would have the ſame Momentum, or a Momentum equal to the Sum of the Momenta of all the Corpuſcles: and it is not leſs certain that a Quantity of Matter or Weight plac'd at O, (which would have, with a Velocity as O, the ſame Momentum as the whole Matter at G with the Velocity C G) muſt be to the Matter concenter'd at G, or to the Weight of the whole Body, or of the Aſſemblage of the Corpuſcles A, B, D, *&c.* in a reciprocal Ratio of their Diſtances from the Axis of Oſcillation: you will then have for the Expreſſion of that Weight, the fourth Term of this Analogy $CO : CG :: \overline{A+B+D, \&c.} : \frac{CG \times \overline{A+B+D, \&c.}}{CO}$. Or that Weight multiplied by the Velocity that it has at O, (which is as C O) gives for the Expreſſion of a Momentum $CG \times \overline{A, B+D, \&c.}$ which muſt be preciſely equal to that which we have deduc'd from the firſt Reaſoning. Thus ſince we have two Expreſſions for the Sum of the Momenta which are felt at O, we ſhall have this Æquation

$CG + \overline{A+B+D, \&c.} = \frac{\overline{CA}^2 \times A + \overline{CB}^2 \times B \times \overline{CD}^2 \times D, \&c.}{CO}$ whence is drawn this Expreſſion $CO = \frac{\overline{CA}^2 \times A + \overline{CB} + \overline{CD}^2 \times D}{CG \times \overline{A+B+D, \&c.}}$. One might alſo have found the Diſtance C O another way; for as ſoon as you have found the Weight where a Quantity of Matter, which being plac'd at O, has the ſame Momentum, with a Velocity as C O, as all the Corpuſcles, A, B, D, *&c.* where they are placed with their reſpective Velocities; namely, $\frac{CG \times \overline{A+B+D, \&c.}}{CO}$ you need only divide by that Weight or Quantity of Matter the Expreſſion of the total Momentum felt at O, already found, and the Quotient will give the Velocity of the Point O, or rather the Diſtance of the Axis, *viz.* C ⊙, ſince the Velocities have always been expreſs'd by the Diſtances of the Axis, which gives exactly the ſame Expreſſion.——Now if inſtead of any Force, we ſuppoſe Gravity to give Motion to this Body, or Aſſemblage of Corpuſcles, it will vibrate as if it was wholly concenter'd or reduc'd to O, as we have juſt demonſtrated it. That is, that one only Corpuſcle placed at a diſtance of the Axis of Vibration, that ſhall be = C O; will perform its Vibrations in the ſame time as the Body performs its Vibrations: and conſequently the Point ⊙ found by the Expreſſion before ſaid, is the true Center of Oſcillation. And therefore, generally the Diſtance of the Center of Oſcillation from the Axis of Vibration is equal to the Product of the Sum of the Squares of the Diſtances of all the Phyſical Points of the Body multiplied by a very ſmall Portion of that Body, ſuch as is conceiv'd

ceiv'd to be in one of his Phyſical Points, divided by the Product of the Weights, or *of the Quantity of Matter of the Body multiplied by the Diſtance of the Center of Gravity from the Axis of Vibration.*

SCHOLIUM.

WE have ſuppos'd in this Demonſtration, that all the Weights or all the Corpuſcles are on the ſame ſide of the Center of Gravity; but the Demonſtration, or its Formule, is not the leſs general: for if we ſuppoſe Weights to be on both ſides of the Center of Suſpenſion, the more the Quantity of the Weights, or of the Matter on each ſide of the Center of Suſpenſion comes near to an Equality, the leſs will be the Diſtance C G of their common Center of Gravity: ſo that if there be as many Weights on one ſide as on the other, the Diſtance C O will be $=$ *o*. And conſequently the Denominator of the Expreſſion being then equal to *o*, the Quantity C O, or the Diſtance of the Center of Oſcillation will be infinitely great; which agrees with Experience, becauſe then the Body will not vibrate at all, but remain in any Poſition in which it is plac'd about its Center of Suſpenſion.

THERE are two Things to be obſerv'd, which the Courſe of this Demonſtration furniſhes us with; the firſt is, that the Sum of the Momenta of all the Particles of a Body, where the total Momentum that acts, or is felt at the Center of Oſcillation, is equal to $CG \times \overline{A + B + D}$, *&c.* That is, to the whole Weight of the Body multiplied by the Velocity of the Center of Gravity: ſo that all the Momenta act, or are felt at the Center of Oſcillation, which conſequently will be alſo the Center of *Percuſſion*; that is, the Point which would give the greateſt Stroke poſſible; but this is only in the Caſe where it is the Center of Oſcillation that ſtrikes an Obſtacle.

THE other thing to be obſerv'd, is, that the Forces that equal Bodies, (ſuch as the Corpuſcles A, B, D, *&c.* have been ſuppos'd to have, becauſe they are ſuppos'd to be felt at the Point $\odot$, where they are all collected) are to one another as the Squares of the Diſtances from the Axis about which they are mov'd or vibrate. Theſe two laſt Remarks are of great Uſe in the Calculation of Machines, or of the Force of Bodies which move round a Center.

TO give the Application of the Rule which we have juſt demonſtrated, (the ſame which *Huygens* has given) we muſt enter into Subtilties of the Doctrine of Fluxions and Fluents, which would not be proper here, and would be uſeleſs to thoſe who are not acquainted with that Doctrine. It will be ſufficient for thoſe who do underſtand it, to take notice, "That " in order to determine the Diſtance of the Center of Oſcillation from

 " the

" the Axis of Vibration, a more convenient, and even a ſhorter manner " than Mr. *Huygens*, they muſt begin by making themſelves Maſters of " the Truth of the two following Lemmas, *viz.* that in a rectangular " Triangle, whoſe Baſis is horizontal and Perpendicular vertical, (calling " the Baſe $= b$, and the Perpendicular $= a$) the Sum of the Squares " of all the Lines that it is poſſible to draw, or to conceive drawn from " the Vertex of the Triangle upon the Baſe, will be preciſely equal to " this Expreſſion $aab + \frac{1}{3}bbb$.

" THE other Lemma abſolutely neceſſary for finding the Diſtance of " the Center of Oſcillation of Spheres, Spheroids, Conoids, Cylinders, " Cones, &c. (ſome or moſt of whoſe Sections are Circles) is reduc'd " to this——The Sum of the Squares of the Diſtances of all the Points of " a Circle from an Axis of Oſcillation conceiv'd in a Plane parallel to the " Plane of the Circle (calling the ſhorteſt Diſtance from the Center of " the Circle to the Axis $= a$; the Radius of the Circle $= r$; and the " Surface of the Circle C) will be $aa + \frac{1}{4}rr \times C$."

BY means of theſe two Lemmas, and the Doctrine of Fluxions and Fluents, you will find the Diſtance of the Center of Oſcillation in the Sphere, the Cylinder, &c. exactly the ſame as *Huygens* has given it in his Treatiſe *de Horologio Oſcillatorio*, to which I muſt refer the Reader, who has a mind to examine the matter more fully. I ſhall only add here, that according to thoſe Rules the Center of Oſcillation of a Sphere ſuſpended by a Point of its Surface will be $\frac{2}{5}$ of the Radius below the Center of that Sphere, or at $\frac{7}{10}$ of the Diameter from the Center of Suſpenſion.

IF the Ball or Sphere be tied to a Thread, the Diſtance of the true Center of Oſcillation will be found in all poſſible Caſes, by the following Analogy.

As the Diſtance between the Point of Suſpenſion and the Center of the Ball :
Is to the Radius, or Semi-Diameter of the Ball : :
So will this ſame Radius be :
To a third Proportional :
Which will be the fourth Term of the Analogy.

THE $\frac{2}{5}$ of this fourth Term; that is, the fourth Term multiplied by 2, and divided by 5, will give the Diſtance of the Center of Oſcillation below the Center of the Ball, which being added to the Diſtance of that Center from the Point of Suſpenſion, will give the true Length of that Pendulum. It follows from this, that if the Body of the Pendulum be very ſmall in reſpect to the Length of the Thread, or the Thread be ſuppos'd very long in reſpect to the Diameter of the Ball of the Pendulum, the

the Center of Oſcillation (in that caſe only) will coincide with the Center of Gravity, or Magnitude of the Sphere or Ball.

By the ſame Rules we find that if a Cylinder be made to oſcillate about one of the Diameters of its upper Baſe, (calling the Height or Length of the Axis of the Cylinder $= a$, and the Radius of the Circle of its Baſe $= r$) the Diſtance between the Center of the ſuperior Circle and the Point of the Axis, which is the Center of Oſcillation of the Cylinder will be $\frac{2}{3}a + \frac{rr}{2a}$; whence it follows, that if the Cylinder is reduc'd to a right Line conceiving its Diameter or Radius $= o$, $\frac{rr}{2a}$ becoming then $= \frac{o}{2a} = o$. Thus the Diſtance of the Center of Oſcillation of a right Line that oſcillates round one of its Ends, will be at $\frac{2}{3}$ of the Length of that Line.

N. B. As moſt People who apply themſelves to theſe kind of Calculations begin with reading Mr. *Carré*'s Book, call'd *Methode pour la Meſure des Surfaces, &c.* I would have them take notice, that the Book is very good upon all the other Subjects that it treats of, except that of the Center of Oſcillation, which the Author has determin'd with Exactneſs, but only in the four firſt Problems of the fourth Section: and thus they muſt not be ſurpriz'd if they find that Monſ. *Carré* gives other Diſtances than the true, (ſuch as $\frac{6}{10}$ of the Diameter, or $\frac{1}{5}$ of the Radius below the Center) for the Diſtance of the Center of Oſcillation of a Sphere, ſuſpended by a Point of its Surface; and $\frac{2}{3}$ of the Axis of the Cylinder, as well as of the right Line, whatever be the Diameter of the Baſe: which is contrary to Experience as well as Reaſoning; ſince it is eaſy to comprehend that Cylinders of different Diameters, tho' of equal Heights, will not oſcillate equally, and like a right Line, or a very fine ſtrait Wire of the ſame Length. Thus Monſ. *Carré*'s Readers muſt ſtop after the four firſt Problems of the fourth Section.

Want of room hinders me from ſaying much more upon this Subject; yet I will add three Problems that I have found very uſeful upon many Occaſions; and which ſuch of my Readers who are only vers'd in common Algebra will be glad to find here: and thoſe who do not underſtand the Reaſoning may yet make uſe of the Concluſions, being ſure not to be deceiv'd, becauſe the whole is built upon Mr. *Huygens*'s Rule, which we have demonſtrated above, and from which we have drawn theſe Conſequences mathematically.

PROBLEM I.

The Length of a Pendulum taken between the Center of Suspension and that of Oscillation being given: it is requir'd to find the Length that must be fix'd between the Point of Suspension and the Surface of the Ball, (whose Diameter is given) that the Center of Oscillation of the Ball may be at the Distance given from the Point of Suspension.

Let the Length of the Pendulum given be $= b$.

The Length requir'd $= x$.

The Radius of the Ball $= r$.

By what has been said above it must be $r + x + \frac{2rr}{5x+5r} = b$.

Therefore $5xx + 10xr + 7rr = 5xb + 5rb$, whence is drawn $5xx + 10xr - 5xb = 5rb - 7rr$; and dividing by 5 $xx \left.\begin{matrix}+2r\\-b\end{matrix}\right\} x = rb - \frac{7rr}{5}$, and substituting $-2c$ instead of $+2r-b$, and d instead of $rb - \frac{7rr}{5}$ you will have

$xx - 2cx = d$, and $xx - 2cx + cc = d + cc$; whence we draw $x - c = \sqrt{d+cc}$, and $x = \sqrt{d+cc} + c$. Which was to be found.

THUS if you would find what Length must be given to a Thread tied to a Ball of an Inch Diameter, that it may vibrate half Seconds; we shall have here $r = 0{,}5$, and $b = 9{,}782$, $2r - b = -2c$ will be $= -8{,}782$; therefore $c = 4{,}391$, and $rb - \frac{7rr}{5}$ will be $= d =$ $4{,}541$, and x will be $= \sqrt{4{,}541 + 19{,}288881} + 4{,}391$, which you will find equal to $9{,}271$ Inches for the Length sought.

PROCEEDING in the same manner for a Ball of half an Inch Diameter to make it swing half Seconds, all will be in the same manner except r, which will then be but equal to 0,25 Inches; and you will then find the Distance requir'd $= 9{,}425$ Inches. It is well to observe, that if you make use of a Thread to make a Pendulum, the Alterations of the Air will often change x, the Length of the Thread, without you measure it often: therefore to have in Practice Pendulums to swing half Seconds or quarter Seconds exactly, it is better to use a little cylindrick Broach drawn in a Wire-drawer's Tool, to make it of the same Diameter all the way, which must be filed as in the Figure, so that there may be a little Hole quite at the Top, that it may make its Vibrations upon a small Axis well polish'd, so placed as to be a Diameter of the upper Base of the Broach or Cylinder. The Length of the Broach contain'd

tain'd between the middle of the Hole at Top, and the Bottom of the Broach, will be found by the following Problem.

PROBLEM 2.

The Diameter or Radius of a cylindrick Bar being given, which is suppos'd to perform its Variations about one of the Diameters of its upper Base, it is requir'd to find how long the Bar must be that the Center of Oscillation may be at what Distance you will from the Point of Suspension.

Let the Length of the simple Pendulum, or the Distance from the Center of Oscillation to that of Suspension be $= a$.

The Radius of the Broach or cylindrick Bar $= r$.

And the Length of the Bar sought for that Purpose $= x$.

We have already said, that then $\frac{2x}{3} + \frac{rr}{2x} = a$, therefore $2x + \frac{3rr}{2n} = 3a$, and $4xx + 3rr = 6ax$, and by Transposition $4xx - 6ax = -3rr$; therefore $xx - \frac{3}{2}ax = -\frac{3}{4}rr$, and $xx - \frac{3a}{2}x + \frac{9aa}{16} = \frac{9aa}{16} - \frac{3}{4}rr$, whence is deduc'd $x - \frac{3}{4}a = \sqrt{\frac{9aa}{16} - \frac{3}{4}rr}$, and lastly $x = \sqrt{\frac{9aa}{16} - \frac{3}{4}rr} + \frac{3}{4}a$. Now let us suppose that it be requir'd to know the Length of a cylindrick Bar, whose Diameter is $\frac{2}{10}$ of an Inch, which oscillating by its End must swing half Seconds; that is, that here $r = 0{,}1$, and $a = 9{,}782$ Inches, you will have $aa = 95{,}687524$ Inches, $9aa = 86{,}187716$ Inches, and $\frac{9aa}{16} = 53{,}824232$ Inches, and $rr = {,}01$, and $\frac{3}{4}rr = {,}0075$, and thus $\sqrt{\frac{9aa}{10} - \frac{3}{4}rr} = \sqrt{\frac{53{,}7947}{53{,}816732}} = 7{,}308$. Wherefore $x = 7{,}308 + \frac{3}{4}a$, or because $a = 9{,}782$, $\frac{3}{4}a = 73365$, and consequently according to the Expression above $x = \sqrt{\frac{9aa}{16} - \frac{3}{4}rr} + \frac{3}{4}a$, the Length requir'd will be $7{,}308 + 7{,}3365 = 14{,}6445$ Inches.

If we wanted the Length of a Broach of the same Diameter, which oscillating by one of its Ends should swing quarter Seconds, then we should have $a = 2{,}4455$ Inches; $r = 0{,}1$ as before, and $aa = 5{,}98047029$ Inches, and $9aa = 53{,}82423225$, and $\frac{9aa}{16} = 3{,}36401451$, and $\frac{3}{4}rr = {,}0075$. Therefore $\sqrt{\frac{9aa}{16} - \frac{3}{4}rr} = \sqrt{3{,}35691451}$, which is equal to $1{,}832$ Inches; which being added to $\frac{3}{4}a = 1{,}834125$, gives for the requir'd Length of the Bar for the Pendulum to swing quarter Seconds $3{,}666225$ Inches.

At the Bottom of Page 446. after Line 35. read,

I was discourag'd from publishing my *Celidography* in my first Volume, by some of our Astronomers, who call'd in question *Bianchini*'s Discoveries; but our worthy President *Martin Folkes* having acquainted me that Signior *Bianchini*, whom he knew very well, was too accurate to make any Mistakes in Astronomical Observations, and too honest to publish any thing that was not exactly agreeable to Truth; I have thought proper to publish it here.

A DISSERTATION *concerning the Planet* Venus, *according to* Bianchini'*s Discoveries, as it is represented by Clock-work in a* Planetarium. *By the Author.*

THE Revolution about the Sun is as before known, *viz.* near 225 Days.

The Revolution about her own Axis is 24 Days, eight Hours; and not 23 Days, as formerly thought.

THE Terrestrial Globe for *Venus* has these Remarkables.

1. THE Angle of the Axis with the Plane of the Ecliptick is 15 Deg.

2. THE Tropicks are 15 Deg. from the Pole, or 75° from the Æquator.

3. THE Polar Circles are 15 Degrees from the Æquator, or 75° from the Poles.

4. THE Plane of a Solar Horizon for the longest Day cuts the Plane of the Æquator at an Angle of 15 Degrees.

5. THE Sun's greatest Declination is 75 Degrees.

6. THERE are but 9 $\frac{1}{4}$ Days in every Revolution round the Sun.

7. To bring the Days to an even Reckoning, every fourth Year must be a Leap Year, which, taking in the four Quarters of a Revolution, will make the Leap Year in *Venus* consist of ten Venereal Days; equal to seven $\frac{1}{2}$ Months of our terrestrial Time.

8. THE long Day for the North Pole will contain 4 $\frac{5}{8}$ apparent diurnal Revolutions of the Sun. Tho' in strictness to one standing on the North Pole, every Point of the Horizon is to the South; yet let us fix a South Point, and that will settle the other Cardinal Points for this Position of the Sphere. Be that then call'd the Meridian which goes thro' the Sun, and the Zenith when it is highest, and the Place where it cuts the Horizon call'd the South: this will determine the East and West, and North on the Horizon. Then will the Phænomena be as follows.

THE Sun will rise 22 $\frac{1}{2}$ Degrees on the North of the East, in an Angle of something under ten Degrees with the Horizon, and moving in a

Spiral, after it has advanc'd 112 ½ Degrees, (to be measur'd upon the Horizon) it will pass the Meridian at an Altitude of ten Degrees; then making one entire Revolution, it will pass the same Meridian at an Altitude of 42 ½ Degrees: making another Revolution, it will again pass the Meridian, as it culminates, at an Altitude of 75 Degrees, or 15 Degrees from the Zenith: thence it will descend again in the same Spiral, and in its Descent cross the Meridian at the Height of 42 ½ Degrees; and lastly, making its fifth Revolution, cross the Meridian at the Height of ten Degrees; and, going on 112 ½, set at a Northern Amplitude of 22 ½ Degrees.

9. THE Phænomena at the South Pole will be *mutatis mutandis*, the same as these.

10. Now let us suppose the artificial Globe representing *Venus* rectified for a Place on the Tropick, where the Sun is vertical at its greatest Northern Declination in the Colure of Solstices; when a Solar Horizon, whose Pole is in the Solsticial Point is also the rational Horizon; and let us call that Colure the Meridian, then we shall observe the following Phænomena.

THE Sun will rise with a Northern Amplitude of 7 ½ Degrees, and always moving in a visible Spiral (in this and all other Positions of the Sphere) come to the Meridian the first time with an Altitude of 25 Degrees; then, without setting, come the second time to the Meridian in an Altitude of 57 ½ Degrees; next, the Sun will come to the Meridian in the Zenith, for the third time; the fourth time it will pass the Meridian with an Altitude of 57 ½ Degrees; the fifth time it will pass it at the Height of 25 Degrees, and at last set with a Northern Amplitude of 7 ½ Degrees. The other half Year for this Place will be Night.

11. FOR the other, or Southern Hemisphere, the Place in the Tropick where the Sun is vertical at the Solstice, will have the same Phænomena, except that the Colure of the Solstices will not be in the same Meridian as it was on the other side, but 45 Degrees more to the West. *N. B.* In a Year the Solsticial Points in the Hemisphere advance 90 Degrees. So that tho' the Spiral in which the Sun's apparent Motion is perform'd, be of the same sort every Year of *Venus*, yet it will not be the very same, (that is, the Sun will not pass vertically over the same Places) till four annual Revolutions of *Venus* are compleated.

12. THE Phænomena in the Æquator will not be the same in every Degree of it, because the Day is so great a Part of the Year; we will therefore here consider two Places of it. The first shall be that Place which is cut by a Colure passing thro' the Solsticial Point in the Northern Tropick; and there the Phænomena of the Sun will be as follows.

When the Sun is in the Northern Signs, it will riſe the firſt Day with 13 Degrees of Northern Amplitude, then come to the Meridian with ten Degrees of Declination, or an Altitude of 80 Degrees: going on in the Spiral, it will ſet with 18 Degrees of Northern Amplitude. The next Day it will riſe with $35\frac{1}{2}$ Degrees of Northern Amplitude, come to the Meridian with $42\frac{1}{2}$ Degrees of Declination, (or an Altitude of $47\frac{1}{2}$ Degrees) and ſet with $50\frac{1}{2}$ Degrees of Northern Amplitude. The third Day the Sun will riſe with 67 Degrees of Northern Amplitude, come to the Meridian with a Declination of 75 Degrees, (which is its greateſt Declination, and at which time the Meridian Altitude will only be of 15 Degrees) and ſet with a Northern Amplitude of 67 Degrees, coming back towards the Æquator. The fourth Day the Sun will riſe with a Northern Amplitude of $50\frac{1}{2}$ Degrees, come to the Meridian with $42\frac{1}{2}$ Degrees of Declination, (or an Altitude of $47\frac{1}{2}$ Degrees) and ſet with $35\frac{1}{2}$ Degrees of Northern Declination. The fifth Day the Sun will riſe with 18 Degrees of Northern Amplitude, come to the Meridian with a Declination of 10 Degrees, (or Altitude of 80) and ſet with 3 Degrees of Northern Amplitude. *N. B.* Theſe Appearances, from 3 Degrees of Northern Amplitude of the Sun at its firſt Riſe the firſt Day, to 3 Degrees of Northern Amplitude at its ſetting the fifth Day, happen during $\frac{1}{8}$ of a diurnal Revolution more than half an annual Revolution of *Venus*.

13. THE ſame Phænomena will happen, *mutatis mutandis*, when the Sun is in the Southern Signs.

14. THE Phænomena of that Place on the Æquator, where the Sun is in the Zenith at Noon, the firſt Day of its half Year's Progreſs, will be as follows. The firſt Day the Sun will riſe about $8\frac{1}{4}$ Degrees South of the Eaſt, come to the Meridian in the Zenith with no Declination, and ſet about $8\frac{1}{4}$ Degrees to the North of the Weſt. The ſecond Day it will riſe with $24\frac{1}{4}$ Degrees of Northern Amplitude, come to the Meridian with $32\frac{1}{2}$ Degrees of Declination, (or $57\frac{1}{2}$ Degrees high) and ſet with $40\frac{1}{4}$ Degrees of Northern Amplitude. The third Day the Sun will riſe with $56\frac{1}{4}$ Degrees of North Amplitude, come to the Meridian with 65 Degrees of Declination, (or 25 Degrees high) and ſet with $73\frac{1}{4}$ Degrees of Northern Amplitude. The fourth Day the Sun will riſe with $62\frac{1}{2}$ Degrees of Northern Amplitude, come to the Meridian with $52\frac{1}{2}$ Degrees of Declination, (or $37\frac{1}{2}$ Degrees high) and ſet with $40\frac{1}{2}$ Degrees of Northern Amplitude. The fifth Day the Sun riſes with about 27 Degrees of Northern Amplitude, comes to the Meridian with 20 Degrees of Declination, (or an Altitude of

of 70 Degrees) and sets with about 12 Degrees of Northern Amplitude.

THIS happens when the Sun is in the Northern Signs, and the same, *mutatis mutandis*, when it is in the Southern Signs.

FROM all this it appears that there can be no right Sphere, or parallel Sphere on this Globe; the Sun's apparent Motion being very oblique to an Observer at the Pole, or at the Æquator, as well as in any other Place.

15. IN respect to the annual Motion, the Sun will appear to go thro' every Sign of the Zodiac in 18 Days, and near $\frac{1}{3}$ of our terrestrial Days, which make a little more than $\frac{3}{4}$ of one Venereal Day.

16. IF it be allow'd me to consider final Causes, I beg leave to make the following Conjecture.

Query. MAY not the Inclination of *Venus*'s Axis, and the odd Number of 9 $\frac{1}{4}$ Days in its annual Revolution, which give the Sun so great, and so quick a Declination, be order'd to prevent the too great Effect of the Sun's Heat, (which, according to *Venus*'s nearer Distance, must be twice greater than it is upon the Earth) by preventing the Sun from shining perpendicularly over the same Countries two Days together? For here the Sun appears to have the same Track but once in four Years. Besides, the Nights being longer, give the heated Soil of the Planet Time to cool.

IF we compare this with *Jupiter*, and consider it in this conjectural way, we shall find the Situation of its Axis, and Quickness of its Revolution about it properly contriv'd for increasing the Effect of the Sun's Heat, whose Quantity is much diminish'd on account of its Distance. The Heat of the Sun at *Jupiter* is but $\frac{1}{27}$ Part of what it is at the Earth; but then as *Jupiter*'s Axis is perpendicular to its Ecliptick, the Sun shines perpendicularly, or nearly so, on the greatest Part of *Jupiter*'s Surface, so that by its constant shining over the same Place, it must in time sufficiently warm it; and, perhaps, *Jupiter*'s Belts are Vapours rais'd out of its heated Soil. The quick Revolution of *Jupiter* about its Axis, which makes the Day something under five Hours long, does not give those Parts which have been heated by Day, Time to cool too fast by Night. If it be alledged that near the Poles of *Jupiter* it must be very cold, it may be answer'd, that the Sun shines upon them every Day, which is not the Case in our Earth, where the Nights are half a Year long: and perhaps the Polar Parts may be inhabited by Animals different from those that live in the torrid and temperate Zones.

POSTSCRIPT.

Air changed, purified, and conveyed from Place to Place, by the Author.

THE Reverend, Learned, and Ingenious Dr. *Stephen Hales* has lately publiſh'd a Book call'd THE VENTILATORS; wherein he deſcribes ſeveral kinds of Bellows of his Invention, which he recommends to publick Uſe for purging of foul Air, and giving freſh Air to Ships, Priſons, Hoſpitals, *&c.* which if made uſe of, will ſave the Lives of Thouſands, who periſh every Year by breathing unwholeſome Air only. I hope he will be rewarded as he deſerves for ſuch a noble Propoſal: or if he finds a Combination againſt him to defeat it, (as I have found upon the ſame Occaſion) he ſtill will be commended by wiſe and good Men, who wiſh well to the Publick, and that is a Reward in the midſt of Diſappointment. As I have made Experiments theſe 28 Years upon the purifying of Air, conveying it from one Place to another, and changing it for the Advantage of thoſe that breathe it in cloſe Places to the Detriment of their Health; and ſtill (to uſe the vulgar Expreſſion) have been *jockey'd out of my Project*: I ſhould have thought it a ſufficient Reward if the Doctor had mention'd, tho' ever ſo lightly, *that I had made ſome Experiments that way*; nay, tho' he had ſaid that my Machine, or *Blowing-Wheel*, (which he had at *Teddington* to make trial of) did not blow near ſo ſtrongly as his Bellows, and therefore muſt be much worſe; tho' my Intention by that Machine was to give freſh Air to ſick People inſenſibly, and therefore I made it but of half the Diameter of the Wheel, which is over the Houſe of Commons, and conſequently of the eighth Part of that, which conveys Air thro' a ſquare Bore of ſeven Inches at the rate of a Mile in a Minute. I believe the Doctor was in ſuch haſte to publiſh his VENTILATORS, that this Omiſſion was pure Forgetfulneſs; for he mentions me in other reſpects; and is ſo far from aſcribing the whole Invention to himſelf, that he ſays, that ſomething like this Method is made uſe of in *Sweden*.

THE

The only Inconveniency I find, is, that I am obliged now to publish an Account of the principal Experiments I have made upon this Subject since the Year 1715; lest I should be look'd upon as a vain Boaster, when I say that I made most of the Experiments mention'd as made and propos'd to be made in the VENTILATORS: unless I give an Account of Facts, and the Date of those Facts.

In the Year 1715, I translated from the *French* a Book call'd *la Mecanique du Feu*, which I knew to be written by *Monsieur Gauger*, a very ingenious Gentleman of *Paris*, tho' he conceal'd his Name. This Book, which I call'd *Fires improv'd*, contain'd many ways of bringing heated Air into a Room to warm it upon occasion, by making it circulate behind Jams or Sides of Brass or Iron with which the Fire-Place is enclos'd, *&c.* I lik'd this better than the way of Stoves, by which stagnant Air is warm'd, and the same Air is breath'd over and over again, which is a very unwholesome way. Now as a Coal Fire takes up less Space than a Wood Fire; to the Author's Book, I added a Method of conveying the Air, that came in, round the Grate very near the Coal Fire, in order to warm the Room as effectually where Coals are used, as Mr. *Gauger* does where Wood is burn'd. But as a great many People are of opinion, that there is a *vivifying Spirit* in Air, and that burning the Air would make it unfit for breathing, by depriving it of that Spirit; I was willing to try whether the thing was so or no; or whether it was not rather the manner of burning the Air, which made it pernicious to Animals, by mixing some unwholesome Effluvia with the burn'd Air. Accordingly I made many Experiments for that purpose, of which I shall only mention a few here. To the Plate covering the Receiver of Plate 25. an Air-Pump, I fix'd a Cock, and a curve Tube of Brass ending in an Iron Fig 27. Tube, so as the End of the said Tube being thrust into a red-hot metalline Cube might not melt, when the Air to be re-admitted into the above-mention'd Air-Pump Receiver was made to pass into the middle of the red-hot Cube, before it enter'd into the Pipe. When the Air had run into the red-hot Cube, and then passing first thro' the Iron, then the Brass Tube, into the exhausted Receiver, (the Cock at the Top of the Plate being open) one might easily lift up the Plate, burn'd Air having as much Elasticity as the Air that had been taken out of the Receiver before; I made use of three different Cubes of Metal, weighing five Pounds each, for these Experiments, in the following manner.

The Iron Cube being made red-hot in a Charcoal Fire, 'till its Heat began to look white, I took it out of the Fire, and set it upon a Brick, so as to put the Iron End of the Pipe that went to the exhausted Receiver near an Inch into its Hole; then turning the Cock on the Plate

of the Receiver, the outward Air having been burn'd in paſſing thro' the Cube, fill'd the Receiver till I could take off the Plate; then putting a Linnet into the Receiver with a Plate over him, the Bird did not ſeem to be affected in half an Hour.

I TRY'D the ſame kind of Experiment with a Copper Cube, and another Linnet was not affected with the Air burn'd this way.

I TRY'D a Braſs Cube, not above half ſo much heated, as the Iron of the Braſs one had been, and I did not find that another Bird of the ſame kind, receiv'd any Damage: but upon heating the Braſs Cube again, 'till its Corners began to melt, the Air was ſo infected with the Steam of the *Lapis Calaminaris*, that another Linnet being put in, died in two Minutes.

THEN I took the Iron Cube, and put it into a Chafing-diſh of Charcoal, ſo that the Air could not paſs into the exhauſted Receiver, without firſt going thro' the burning Charcoal; another Bird put into the Air thus foul'd, died in an Inſtant, and a Candle let down into this Air, went out immediately, clearing about an Inch of that Air; another Piece of lighted Candle was let down a little lower, purging the Air as low as it went, 'till five or ſix Pieces of Candle ſucceſſively let down, purg'd the whole Air; ſo that another Bird was let down then without receiving any Hurt.

WHEN the Air was let in thro' the Flame of Spirit of Wine before it went into the red-hot Cube, it prov'd as mortal to a Bird as the Time before.

THE way that Mr. *Haukſbee* made the Experiment formerly, was in the following manner: He took a Piece of Braſs of the ſhape of a Vinegar Cruet, and having bor'd a Hole, down the Neck of it as far as the larger Part, plac'd it in a Chafing-diſh of burning Charcoal, having thruſt into it the Pipe that came from the exhauſted Receiver, which Pipe being of Braſs, he ſecur'd from melting to the Braſs Lump, by Pieces of Iron Wire thruſt in between the Pipe and the Lump. Upon opening the Cock to let the Air into the Receiver, it is plain that this was not meerly burning of the Air; but driving in along with it the Steams of the Charcoal and the Braſs.

THE late Mr. *Worſter* having read of burning Air, but not of my Method of doing it, immediately declar'd againſt the new Contrivance that I countenanc'd, without having read my Book; for I won't ſuppoſe that he could declare ſo poſitively againſt my Method of warming Rooms, if he had read my Account of the fore-mention'd Experiments. The *vivifying Spirit*, which he ſaid was contain'd in the Air, was only an Aſſertion of his own without Proof; for Dr. *Hales* has ſince ſhewn, that

that there is no ſuch thing as that *vivifying Spirit*. Some other People have as raſhly determin'd againſt my Method.

THO' meerly burning the Air does not make it worſe for breathing, and we know that Lightning purifies it, by burning away a great many of thoſe ſulphureous Particles that often float in too great Plenty in the Air: yet to avoid all Objections, I never brought in the Air thro' red-hot Pipes paſſing thro' the Fire; but (tho' I was oblig'd to bring my Conduit for the Air round a Sea-Coal Fire much nearer together than Mr. *Gauger* did round his Wood Fires, which took up more room than a Coal Fire) yet I always made my Tubes to bring in the Air of Plate Iron, (found to be innocent by Experiment) and of five or ſix Inches Diameter: ſo that this Air was no more heated than it would have been by a Summer's Sun; and the Air introduc'd came immediately from without doors: ſo that the whole Air of the Room was often chang'd in a quarter of an Hour, and had none of the old Unwholeſomeneſs and Inconveniency of a *German* Stove; where the ſame Air is heated, even to the Suffocation of thoſe that are not uſed to it.

HIS Grace the Duke of *Chandos* has had two of theſe Machines about five or ſix and twenty Years in his Library, and never found any Inconveniency from the Uſe of them; as alſo twenty or thirty Perſons more, who had them from the Beginning of my applying the Invention.

NOW as I took ſo much Pains and Care, and was at ſome Expence to make this Management of Air uſeful, I can't help complaining of thoſe that endeavour'd to defeat me in it.

A MAN who came from *France*, without knowing any thing of Mr. *Gauger*'s Contrivances, but pretending to be the Author of his Book, (becauſe it had no Name to it) got my Tranſlation of *Gauger*'s Book, and carried it to a famous Brazier, to inſtruct him how to make one of the Machines for his Grace the late Duke of *Kent*, for whom he had promis'd to ſet up one; and coming to me to get more Light into the matter, ſhew'd me the *French* Book, which he ſaid he had written: but upon my calling him Mr. *Gauger*, (having never ſeen that Author) he told me then he had only written the Book jointly with Mr. *Gauger*; and I found, upon Trial, that he could not read three Pages of the Book together. Notwithſtanding this, he had the Impudence to apply to Count *Bothmar*, and to Monſ. *Robethon*, to repreſent him to his late Majeſty as a poor ingenious Man, who had found out a noble Invention, that deſerv'd a Patent, which he could not pay for.

HIS *Majeſty* and thoſe Gentlemen were ready to pay for the Man's Patent; but when I heard of it, I thought it hard that I ſhould by that means

means be excluded from an Invention, that Monſ. *Gauger* had given the Publick in *French*, and I had ſince publiſh'd in *Engliſh* with Improvements: and therefore, tho' I was offer'd half the Patent without any Expence, I rejected it.

In the Year 1720, with my Workman *William Vreem*, I contriv'd ſeveral Methods of drying Malt with hot Air, but deferr'd getting out the Patent for the Invention, 'till I could, by proper Experiments, demonſtrate, that it would be an Advantage to the Trader, as well as to a Gentleman, who might make Beer with that ſort of Malt out of Curioſity. In the mean time *Captain Buſby*, a *Buckinghamſhire* Gentleman, inform'd himſelf of me of my Experiments, and told me, that having a Kiln in *Buckinghamſhire*, if I would lend him my Workman, he would make ſome further Experiments, and acquaint me with the Succeſs of them. I did ſo: and the next News I heard about it was a Letter from him, to acquaint me that he had found out an excellent Method of drying Malt by hot Air; for which he had ſet up a Subſcription, and I might be welcome to take as many Shares in it as I pleas'd, paying for them the rate of other People. I made no Anſwer to ſuch a Propoſal; but heard in a little time after, that he had gain'd twenty thouſand Pounds by this Project, and loſt it again in the *South-Sea*.

In the Year 1723, I apply'd this Invention to the clearing the Houſe of Commons of foul Air, which I did in the following manner:

At each Corner of the Houſe in the Cieling there is a Hole which was the Bottom of a truncated Pyramid going up ſix or eight Feet into the Room over the Houſe, ſet up by Sir *Chriſtopher Wren*, to let the Air (made foul by the Breath of ſo many People, and the Steam of the Candles when uſed there) go out; but it ſo happen'd, that when the Tops of the Pyramids were open'd, the Air above being colder, and conſequently denſer, puſh'd down with Violence into the Houſe, and became a Nuiſance to People that ſate under thoſe Holes. I caus'd two Cloſets to be built at each End of the Room above the Houſe of Commons between two of the Pyramids above-mention'd; and leading a Trunk from thoſe Pyramids to the ſquare Cavities of Iron, that went round a Fire Grate fix'd in the Cloſets; as ſoon as a Fire was lighted in thoſe Grates about Twelve o'Clock at Noon, the Air came up from the Houſe of Commons thro' thoſe heated Cavities into the Cloſets, and ſo went away up their Chimneys.

Mrs. *Smith*, the Houſekeeper, who had Poſſeſſion of the Rooms over the Houſe of Commons, not liking to be diſturb'd in her Uſe of thoſe Rooms, did what ſhe could to defeat the Operation of theſe Machines; which ſhe at laſt compaſs'd by not having the Fire lighted,

'till the Houſe had ſate ſome time, and was very hot: for then the Air in the Cloſets, that had not been heated, went down into the Houſe to an Air rarer, and leſs reſiſting, whereby the Houſe became hotter, inſtead of being cool'd. But when the Fire had been lighted before the meeting of the Members, the Air went up from the Houſe into the Cloſets, and out of their Chimneys, and continued to do ſo the whole Day, keeping the Houſe very cool.

A LITTLE after this I made the Houſe of Lords warm, by a Contrivance, which, checking the cold Air that ran in from all Parts violently thro' the Fire, and thereby ſtarv'd the Backs and Legs of thoſe that ſtood near enongh to burn their Shins, ſuffer'd only ſo much to go up the Chimney, as would keep the Fire burning, whilſt the reſt that was heated was drove back into the Houſe, where it was diffuſed, and warm'd every body comfortably. N.B. *This Machine is deſcrib'd in the laſt Edition of my* FIRES IMPROV'D, *and is ſtill in uſe in the Houſe of Lords.*

IN the Year 1727, I contriv'd a Machine for the late Earl of *Weſtmoreland*, to clear a Coal, Lead, Copper, or any other Mine, from any kind of Damp, be thoſe Damps ſpecifically lighter, or ſpecifically heavier than common Air: of which I ſhew'd the Royal Society ſeveral Experiments, of which the Account is printed in the Tranſactions in the following Words.

An Account of Experiments with an Engine to draw Damps or foul Air out of Mines, by the Author; taken from N° 400. *of the Tranſactions of the Royal Society, in the Year* 1727.

THE Engine conſiſts of a triple Crank working three Pumps, which both ſuck and force Air, by means of three Regulators, and are alternately applied to drive Air into, or draw it from any Place aſſign'd, thro' ſquare wooden Trunks; which being made of ſlit Deal, and ten Inches wide in the Inſide, are eaſily portable, and join'd to one another without any Trouble.

EXPERIMENT I.

I FILL'D a tall cylindric Glaſs with the Steams of a burning Candle, and burning Brimſtone Matches, ſo that a lighted Candle would go out almoſt as ſoon as it was let down into it. Then fixing the Trunks to the forcing Hole of the Engine, I drove freſh Air into the Bottom of the above-mention'd Receiver; ſo that the foul Steam came out at the Top of the Receiver.

EXPERIMENT 2.

HAVING fill'd another Receiver (close at top) with foul Steams, as before, I plac'd it in a Position almost horizontal, only with the close End, something above the open End, that the foul Steam might not go out of itself, when specifically lighter than common Air. I fix'd the Trunks to the sucking Hole of the Engine; and by working the Engine drew out the foul Steams from every Part of the Receiver, as the Trunks were applied to them successively.

EXPERIMENT 3.

HAVING fill'd with foul Steams, and set upright the cylindric open Receiver, I applied the Trunks to the sucking Part of the Engine with their open End near the Bottom of the Receiver. Then, by pumping, the Steams were all drawn downwards, and so out thro' the Trunks.

EXPERIMENT 4.

HAVING set a Candle in the cylindric Receiver above-mention'd, without having fill'd it with Steams, and let down the Trunks into the Receiver below the Flame of the Candle, I laid the wet Leather over the Mouth of the Receiver, leaving about half an Inch open for the Air to come in; notwithstanding which, the Candle began to dwindle, and was ready to go out; but working the Engine with the Trunks join'd to the forcing Part, the Candle reviv'd, and burn'd at last as well as in the open Air. When I had left off pumping, the Flame of the Candle diminish'd again; but when it was ready to go out, it reviv'd again upon forcing in more Air with the Engine.

WHEN Damps in Mines are specifically lighter than common Air, they will be driven out of the Mine by the first Experiment.

WHEN Damps are specifically heavier than common Air, they may be sucked out by the second or third Experiment.

WHEN a Sough, or Adit, is carried from a Mine to any distant Valley, to discharge the Water, or save the Trouble of raising it quite to the top of the Pit, Shafts or perpendicular Pits are generally sunk from the Surface of the Earth to the said Sough, to prevent the Workmen from being suffocated as they dig the Sough, and that at a great Expence; but by EXPER. 4. fresh Air may be driven down to the Workmen, to continue their breathing free and safe, and to keep in their Candles; by which means the Expence of perpendicular Shafts will be sav'd.

It has been found by ſeveral Experiments, that a Man may breathe a Gallon of Air in one Minute, and a Candle of ſix in the Pound will burn nearly as long in the ſame Quantity of Air; ſo that a large Engine will abundantly ſupply Air for the burning of Candles, and the working of a great number of Men in a Mine.

The Engines work with a great deal of Eaſe, becauſe no Preſſure of Atmoſphere is to be remov'd; only a Velocity to be given to one ſort of Air, to change it for another.

Fire will not do in all caſes, tho' in ſome it will draw foul Air out of Mines with ſucceſs; becauſe ſeveral ſorts of Damps extinguiſh Fire, and ſome fulminate, and are dangerous when Fire comes near them; and even in common ſtagnant Air, Fire will not keep in long.

Large Bellows have ſometimes been made uſe of for this purpoſe; but they require a much greater Power to produce the ſame Effect, and cannot have the Advantage of being immediately chang'd from forcing to ſucking; neither are they ſo cheap as the propos'd Engine, which may be all made of Wood, except the Crank, which muſt be of Iron, and the Barrels of very thin Copper. The Crank being a Foot long, and the Barrels a Foot and an half Diameter, one Man may diſcharge about thirteen cylindric, or ten cubic Feet, of Damp from the Bottom of the Mine in a Minute.

In the Year 1736, Sir *George Beaumont*, and ſeveral other Members of the Houſe of Commons, obſerving that the Deſign of cooling the Houſe by the Fire-Machines above deſcrib'd, was fruſtrated, aſk'd me if I could not find ſome Contrivance to draw the hot and foul Air out of the Houſe, by means of ſome Perſon that ſhould entirely depend upon me; which when I promis'd to do, a Committee was appointed to order me to make ſuch a Machine, which accordingly I effected, calling the Wheel a centrifugal, or blowing Wheel, and the Man that turn'd it a Ventilator.

This Wheel, tho' in ſome things like *Papin*'s *Heſſian* Bellows, differs much from it, being more effectual, and able to ſuck out the foul Air, or throw in freſh, or to do both at once, according as the Speaker is pleas'd to command it, whoſe Order the Ventilator waits to receive every Day of the Seſſions, the Wheel being ſtill in uſe.

This Wheel is deſcrib'd in N° 437. of the *Philoſophical Tranſactions*, in the following Words.

An Account of an Inſtrument *or* Machine *for* changing the Air of the Room *of ſick People in a little time, by either drawing out the foul Air, or forcing in freſh Air; or doing both ſucceſſively, without opening Doors or Windows.*

N. B. *The Model of this Machine, made by a Scale of an Inch to a Foot, was ſhewn the* Royal Society *the thirteen Day of* June, 1734. *By Dr.* J. T. Deſaguliers, *F. R. S.*

Fig. 1. REpreſents a Caſe D E C B, containing a Wheel of ſeven Feet in Diameter, and one Foot thick; being a cylindrical Box, divided into 12 Cavities by Partitions directed from the Circumference towards the Center, but wanting nine Inches of reaching the Center, being open towards the Center, and alſo towards the Circumference, and only clos'd at the Circumference by the Caſe, in which the Wheel turns by means of an Handle fix'd to its Axis A, which Axis turns in two Iron Forks, or half concave Cylinders of Bell-metal, ſuch as A, fix'd to the upright Timber or Standard A E.

FROM the middle of the Caſe on the other ſide behind A, there comes out a Trunk or ſquare Pipe, which we call the Sucking-Pipe; which is continued quite to the upper Part of the ſick Perſon's Room, whether it be near or far from the Place where the Machine ſtands, in an upper or lower Story, above or below the Machine. There is a circular Hole in one of the circular Planes of the Machine of 18 Inches Diameter round the Axis, juſt where the Pipe is inſerted into the Caſe, whereby the Pipe communicates with all the Cavities; and as the Wheel is turn'd ſwiftly round, the Air which comes from the ſick Room is taken in at the Center of the Wheel, and driven to the Circumference, ſo as to go out with great Swiftneſs at the Blowing-Pipe B, fix'd to the ſaid Circumference.

As the foul Air is drawn away from the ſick Rooms, the Air in the neighbouring Apartments will gradually come into the Room through the ſmalleſt Paſſages: But there is a Contrivance to apply the Pipes which go to the ſick Room to the Blowing-Pipe B, while the Sucking-Pipe receives its Air only from the Room where the Machine ſtands. By this means freſh Air may be driven into the ſick Room after the foul has been drawn out.

THIS Machine would be of great uſe in all Hoſpitals, and in Priſons: It would alſo ſerve very well to convey warm or cold Air into any diſtant Room; nay, to perfume it inſenſibly, upon occaſion.

Fig.

Fig. 2. REPRESENTS the Inſide of the Flat of the Wheel which is fartheſt from the Handle, and next to the Sucking-Pipe.

1, 2, 3, 4. REPRESENTS the Cavity or Hole which receives the Air round the Axis, having about it a circular Plate of Iron to hold all firm; which Plate is made faſt to the Wood, and to the Iron Croſs that has the Axis in it.

g g g DENOTES, by a prick'd Circle, a narrow Ring of thick Blanketting, which (by preſſing againſt the outſide Caſe, whilſt it is fix'd to the outſide of the Flat of the Wheel) makes the Paſſage into the Wheel tight.

H H H is another Circle of Blanketting, likewiſe fix'd to the outſide of the Wheel, and rubbing againſt the Caſe, that the Air violently driven againſt the inner Circumference of the Caſe, may have no way out, but at the Blowing-Pipe at B.

THERE is on the outſide of the other Flat of the Wheel, where the Handle is fix'd, a Ring of Blanketing, like H H H, oppoſite to it; but none oppoſite to *g g g*, becauſe the Wood there is not open, but comes home cloſe to the Axis.

Fig. 3. GIVES a vertical Section of the Wheel and Caſe a little forward of the Axis, drawn by a Scale twice as large as that of the other two Figures.

A *a*, the Axis ſupported by the Irons A, *a*, cylindrically hollow'd, except the upper Part, where a Pin keeps in the Axis.

B D, the Caſe with the Sucking-Pipe S *a*.

E A, the Prop for one End of the Axis.

1, 2, the Opening into the Wheel.

g g, the Eminence of the Wood, to which is fix'd the ſmall Ring of Blanketting.

THE four black Marks, one of which is near H, repreſent the Sections of the two other Rings of Blanketting.

N. B. *There is no need for the Blanketting about the Circumference of the Wheel.*

IN the latter End of the Summer of the Year 1740, the Lords of the Admiralty order'd me to ſhew them the Model of my centrifugal Wheel and Air-Pipes; which having done, ſome of their Lordſhips did me the Honour to go to the Houſe of Commons, to ſee the Operation of the Wheel fix'd there. Sir *Jacob Ackworth* attended them, and ſeem'd to approve the Machine as well as they did: and I was order'd to make a Blowing-Wheel with its Pipes, to be try'd on board the *Kinſale* at *Woolwich*; but leſs than that at the Houſe of Commons, that it might not take up too much room in the Ship.

SIR

Sir *Jacob* appointed a Day for Mr. *Clutterbuck*, (one of the Lords of the Admiralty) and himſelf, to go and ſee the Experiment: and tho' I alledg'd that the Machine could not be done by that Time, he ſtill inſiſted upon the Day, and I made the Carpenter work all Night; but yet we could only ſend the Machine down in Parts, which Mr. *Clutterbuck* could not ſtay to ſee put together that Day.

Sir *Jacob* appointed another Day to ſee the Experiment; but when I came down with my Carpenter, who had put up the Machine, he found ſome Excuſe not to be there, but order'd ſomebody belonging to the Yard to ſee the Experiment.

There was a wooden ſquare Trunk, whoſe Bore was three Inches by five, (which we may call the Sucking-Pipe) reaching from the Carpenter's Store-room to the Engine, that was fix'd between Decks about the middle of the Ship, and another Pipe of the ſame Size going from the Engine two Feet out above Deck.

A Smoke being made in the Carpenter's Store-room with Pitch, and other ſmoky Subſtances, then the Engine was ſet to work. After two or three Turns of the Wheel, holding one's Head over the Mouth of the Pipe above Deck, one might ſmell the Pitch and ſtinking Smoke; and holding a Sheet of Paper over the Hole, it was violently blown out of the Hand, and the Smoke came out black as from a Chimney, 'till the whole Store-room was clear'd of the Smoke and Stink.

Then the Valves about the Engine being chang'd from ſucking to forcing, (as there were written Directions for that purpoſe) a Smoke and Smother was made in the fore part of the Ship between Decks, and twenty or thirty Perſons went down, and forwards, 'till they were within the Smell of the Fumes, and very hot. Then the Wheel being turn'd for blowing forwards, or forcing, the Smoke and Stink were firſt met by the Company, and having paſs'd by them, freſh Air follow'd, which made them as cool as upon Deck. Another Company coming after, at ten Yards diſtance, firſt met the Stink, and then the freſh Air.

All Perſons preſent commended the Machine; only an old Man or two, who had been at *Jamaica*, grumbling, told my Carpenter, that tho' this was the beſt thing he had ever ſeen, he was ſure it would not be ſuffer'd to be put in practice.

After this I waited on Sir *Jacob Ackworth*, who ſeem'd to me from Report to like the Machine well; but told me, there was no occaſion for my going down the next time; but that my Carpenter would be ſufficient to ſhew him the Experiment: ſo accordingly *Kembel Whattley*,

Whattley, my Carpenter, went down to make the Experiment, of which his following Letter is an Account.

To the Reverend Dr. DESAGULIERS.

SIR, *Weſtminſter*, 1740.

" AS you order'd me, I went down to *Woolwich* to attend on Sir " *Jacob Ackworth*, and I met him on board the *Kinſale*, to try " the Experiment on the Air-Machine; and as he came on board he " was very complaiſant to me, and aſk'd me if I was the Perſon that " was appointed by *Dr. Deſaguliers* to attend him, in order to try " the Experiment of the Air-Machine, and I told him I was. Then " ſaid he to the Men, hoiſt the Wind-ſails, and the Wind-ſails were " hoiſted. Now, ſays he to me, we have cut two Scuttle-Holes at " each End of the Ship, and you ſhall ſee what the Wind-Sails will " do, it is our old way when at Sea; and while they were hoiſting the " Sails, I went down under Deck to put the Engine in order. But " I had not been there long, before I was call'd for. So when I came " up, it was to ſee that the Wind-Sails, that were put down, would " blow out a Candle at one of the Scuttle-holes. Now, ſaid he, I " would have you work the Engine, and ſee whether that will throw " out ſo much Air as our Wind-Sails you ſee do. Lord, Sir, ſaid I, " that, I imagine, was not the Intent of the thing; it was to draw " out the foul Air from any Part of the Ship, that there were Tubes " to convey it from: it is impoſſible that a thing, which is but three " Inches by five, ſhould throw in as much Air, as a thing two Feet " ſix Inches Diameter. So we talk'd a-while, and at laſt he told me " that he could not ſtay, but that he had thought ſo before, and that " he was ſorry that the Machine would not do. Pray, Sir, ſaid I, let " there be a great Smoke made in the Carpenter's Store-Room, and ſee " whether the Engine, or your Wind-Sails will deſtroy it firſt. Then " he told me, that he could not poſſibly ſtay; but that Gentleman there, " ſaid he, pointing to a pretty luſty Man that was preſent, ſhall be " with you, and he and you may try the Machine as you pleaſe, and " I ſhall think the ſame of it from his Report, as if I were preſent. " So, Sir, it was then left to the Gentleman and me to try it; and I " burn'd Pitch in the Carpenter's Store-room, and made a great " Smoke, and order'd the Engine to be work'd, and it draw'd it out " in leſs than five Minute's time. Then I turn'd the Valves, and

" brought

" brought in fresh Air; and, as I thought, it gave the Gentleman entire Satisfaction: but however, we made as great a Smoke as before, " and put down the Wind-Sails, and then the Smoke was driven into " several Parts of the Ship, and that not in half the Time that your " Engine did it in; and then it went out above Deck. Sir *Jacob* told " me afterwards, that he was sorry that it succeeded no better, but he " thought it might be a very pretty thing in a House. Sir *Jacob* desires his humble Service to you; and when you come to Town, I " shall be sure to wait on you with the best Account of the whole Affair, which I can't so well express in writing, and am, Sir,

Your humble Servant to command,
KEMBEL WHATTLEY."

NOW let every impartial Person judge, whether I have not reason to complain; for not one of the Lords of the Admiralty, (who talk'd of having many of these Machines for the Preservation of the Health of the Persons then going to *Jamaica*) so much as saw the Experiment made. Nay, Sir *Jacob* himself, who condemn'd the thing, did not once see it; but made his Report from another Reporter, whom he left behind to give him an Account.

THUS ended my Scheme, which I hoped would have been of great Benefit to the Publick.

LAST Year a Man came to the Royal Society, and brought a Contrivance with Copper Tubes, to bring all the foul Air of a Ship into the Fire under the Boiler in the Cook-room, to be discharg'd that way. I said then I dislik'd it, because the Air from the bulg'd Water, and all Sulphureous Steams, were in danger of taking fire, and by their Explosion putting a Ship in danger. This I hinted at in my former Paper, above quoted, out of the Transactions, N° 400.

ACCORDINGLY I am inform'd by one of the Lords of the Admiralty, that there is a Letter come to their Board, from a Captain abroad, informing them, that, as he was making use of this Machine, the foul Air went off with an Explosion.

THE Reverend and Ingenious Dr. *Hales*, who has my little Wheel by him at *Teddington*, has made Bellows, which blow much more strongly, of which he has given a Description in his Book lately publish'd, call'd THE VENTILATORS; an Invention, which, I hope, will meet with due Encouragement; because it may preserve the Lives, and Healths, of a great many People, in a great number of Cases.

FINIS.

AN ALPHABETICAL INDEX FOR THIS SECOND VOLUME.

A

B

V

THE END.

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